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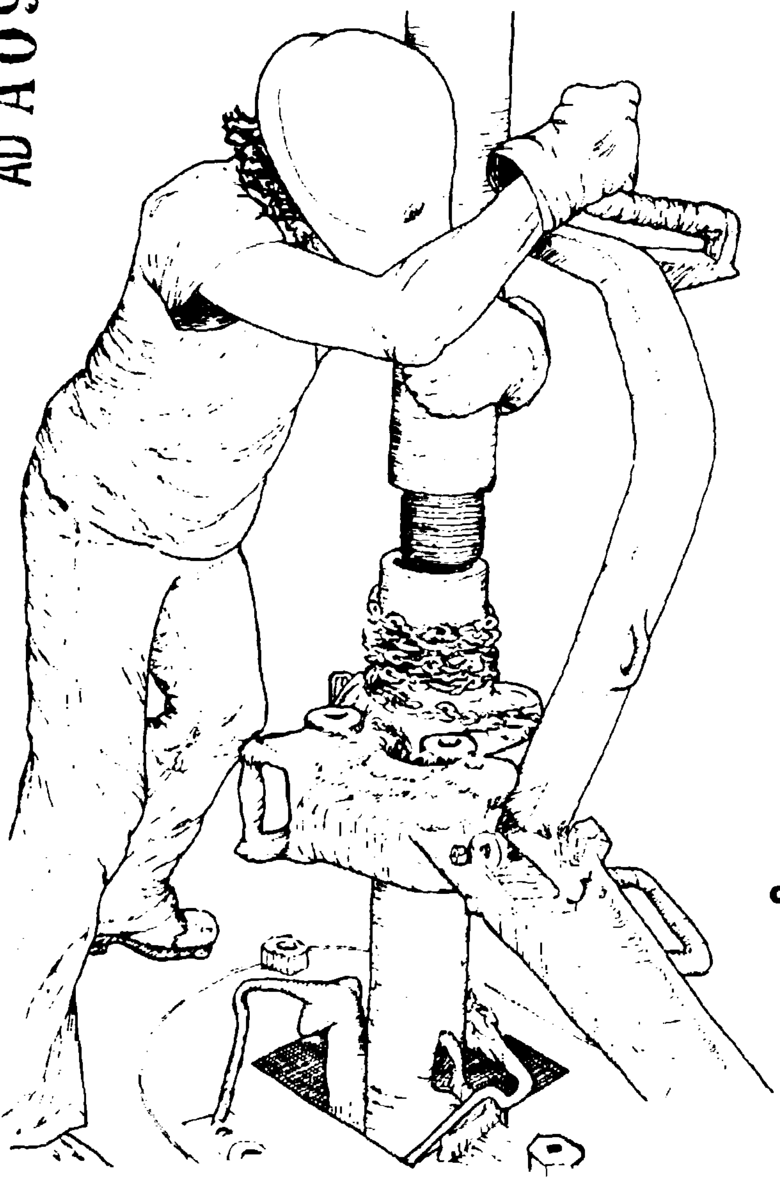
draft programmatic environmental impact statement:

U. S. LAKE ERIE NATURAL GAS RESOURCE DEVELOPMENT



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A detailed analysis of the environmental impacts associated with development of natural gas resources beneath U.S. waters of Lake Erie bordering the states of New York, Pennsylvania, and Ohio. A reference program was developed that sets forth realistic assumptions concerning operational procedures and constraints, Federal and State program administration, level of industry involvement and gas production, and the impacts of this program on air and water quality, ecology, noise, land use, safety, economics, recreation, water supplies, erosion, navigation, etc. are examined. The document sets forth guidelines for environmental (con't)

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20. protection which represent minimum standards acceptable to the Federal government if gas development in principle is ultimately approved for U.S. Lake Erie.

12

DRAFT PROGRAMMATIC

ENVIRONMENTAL IMPACT STATEMENT:

U.S. LAKE ERIE NATURAL GAS RESOURCE DEVELOPMENT

Prepared by
U.S Army Corps of Engineers,
Buffalo District and the
U.S Environmental Protection
Agency, Region V

This Draft Environmental Impact Statement (EIS) is of a programmatic nature. A programmatic EIS assesses the effects of a broad proposal, such as gas development, over a large area or region. Initial program statements present sufficient information regarding the generic impacts of an action so that decision makers can make a reasoned judgement on the merits of the action at the present stage of planning or development. The use of a programmatic EIS is such that it can be followed up with site-specific statements or supplements, as necessary, which may refer back to the original EIS for general discussions and concentrate on the issues specific to the statement or supplement subsequently being prepared. This particular programmatic EIS on gas resource development will be used to determine the environmental acceptability of gas development in U.S. Lake Erie in principle under a given set of constraints and a given program. If gas development is ultimately found acceptable, future specific proposals by applicants could be assessed on a site-specific basis with this programmatic EIS being referenced. Specific information concerning public and private need for each operation could be detailed for each application.

DRAFT PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT:
U.S. Lake Erie Natural Gas Resource Development
in Offshore Waters of New York,
Pennsylvania, and Ohio

Responsible Lead Agency: U.S. Army Engineer District, Buffalo
Responsible Cooperating Agency: U.S. Environmental Protection Agency, Region V

Type of Action: Administrative; Corps Permit Action

The proposed action under consideration is the issuance of permits by the U.S. Army Corps of Engineers (Corps) and U.S. Environmental Protection Agency (USEPA) to lessees engaged in state-initiated development of offshore gas in Lake Erie. The regulatory involvement of the Corps is related to its authority to issue or deny permits under Section 10 of the River and Harbor Act and Section 404 of the Clean Water Act. USEPA has review responsibilities for Section 10 and Section 404 permit applications and also for developing effluent guidelines for the oil and gas industry and standards for air and water quality for Lake Erie. The study was initiated through an Interagency Agreement between the Corps and USEPA in anticipation of applications for federal permits related to various gas development activities. The action will culminate in the issuance of a Final Environmental Impact Statement that will allow a determination of whether or not U.S. Lake Erie gas development can be accomplished in an environmentally acceptable manner and, if so, under what circumstances.

For further information on this statement, please contact:

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DISCLAIMER

The reviewer is cautioned that any reference to trade names, commercial products or processes, and various information available through purchase in this Environmental Impact Statement does not constitute endorsement or recommendation for use by the U.S. Army Corps of Engineers and U.S. Environmental Protection Agency.

SUMMARY

DRAFT PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT:
U.S. Lake Erie Natural Gas Resource Development
in Offshore Waters of New York,
Pennsylvania, and Ohio

S.001

1. Type of action. Administrative; Corps permit action under the jurisdiction of Section 10 of the River and Harbor Act and Section 404 of the Clean Water Act.

S.002

2. Purpose and need. The proposed action under consideration is the issuance of permits by the U.S. Army Corps of Engineers (Corps) and U.S. Environmental Protection Agency (USEPA) to lessees engaged in state-initiated development of offshore gas in Lake Erie. In the absence of a project advocate and project proposal, lease sales by New York, Pennsylvania, and Ohio were postulated and a Reference Program was developed that sets forth realistic assumptions concerning operational procedures and constraints, federal/state program administration, level of industry involvement, gas production, etc. The Reference Program contains a set of guidelines incorporating state-of-the-art technologies and strict operational procedures designed to minimize possible releases to the environment of materials used and residuals generated. This Reference Progam and accompanying guidelines will be subjected to a test of environmental acceptability. After the Environmental Impact Statement (EIS) is publicly reviewed as a Final EIS, the Corps and USEPA will determine whether U.S. Lake Erie natural gas resource development can be: (1) approved as defined in the Reference Program, (2) approved as defined with qualifications, or (3) disapproved as unacceptable in principle. Evaluation of alternative control programs is deferred pending permit application.

S.003

3. Areas of controversy (issues).

(a) Availability of natural gas to regional industrial energy consumers
(b) Need for offshore Lake Erie gas development
(c) Profitability of Lake Erie gas development to industry operators
(d) Availability of gas resources beneath the Lake
(e) Administration and regulation of offshore gas development
(f) Alternatives to offshore Lake Erie gas development
(g) Potential significant impacts resulting from the following offshore program activities or phenomena:

- disposal of residuals
- disturbance of toxic sediments
- accidents

(h) Problems for offshore gas development caused by regional seismic activity (earth tremors or quakes) or Lake Erie ice

(i) Potential significant impacts from offshore development of gas to the following resources:

- water quality
- aquatic ecology
- potable water
- land use
- recreation
- ports, shipping, and navigation
- cultural resources

4. Conclusions.

S.004

(a) The Lake Erie region is net importer of natural gas. Although 2037 BCF of gas was delivered to consumers in New York, Pennsylvania, and Ohio during 1977, only 200 BCF of gas was produced within the three states during the same period. A large portion of the natural gas imported into the region is piped from southwestern producing states. Currently (Fall 1980), there is a temporary surplus of natural gas regionally and nationally which has resulted from some fuel switching, conservation measures, increased wellhead prices allowed through the Natural Gas Policy Act, and state incentives for increased local production. No natural gas shortages are predicted at this time. However, the heavily industrialized Lake Erie region could experience a repitition of events that resulted in a gas availability crisis and imposed user curtailments during the heating seasons of 1976-1977 and 1977-1978.

S.005

(b) It is important to emphasize that this Draft EIS has been developed without the benefit of a project advocate (applicant) and it has therefore been necessary to postulate purpose and need based on realistic assumptions and information. The need for U.S. Lake Erie natural gas has varied greatly over the past 30 years, depending partly on the perspective from which the problem is viewed. However, the region bordering the southern shore of Lake Erie is a national industrial center, a net importer of energy resources, including natural gas. For the purpose of this EIS the impetus for development is defined as an attempt by the three states to provide a more secure natural gas reserve and provide flexibility in supply sources.

S.006

(c) Using pricing and production assumptions as outlined in the Reference Program, an economic evaluation of net present value and return on investment has demonstrated that offshore development can be profitable for industry operators. The program remains profitable even if production estimates are decreased by as much as 20%.

S.007

(d) Numerous geologic studies have led to the generally accepted conclusion that gas-bearing formations underlie U.S. waters of Lake Erie. Formations of primary interest are Lower Silurian Clinton-Medina

sandstones and Middle Silurian Lockport Formation biohermal reef structures. Within a broad band of deltaic sandstones that make up the Clinton-Medina formations, abundant gas is expected from wells in central and eastern Lake Erie. Under Reference Program assumptions, one well will be drilled on every 640 acres of nonrestricted lake bottom; 65% of these wells will be successful in Ohio; 70% will be successful in Pennsylvania; and 85% will be successful in New York. Gas-bearing Lockport reefs are postulated to exist in Ohio waters of Lake Erie. These Middle Silurian Lockport Formation reef structures are more widely scattered and their locations are not easily predicted. Confirmation of the presence of gas-bearing structures in U.S. waters of Lake Erie would require industry purchase and interpretation of existing seismic data or collection and interpretation of new data in addition to on-structure exploratory drilling. Lockport reefs--which are localized, structural gas traps--will yield an even greater pecentage of productive wells than stratigraphic Clinton-Medina sandstones.

S.008
Cumulative gas produced over the lifetime of the Reference Program is estimated at 1.2 TCF in Ohio, 0.15 TCF in Pennsylvania, and 0.17 TCF in New York. Cumulative state revenues generated from cash bonus bids, delay rental fees, and gas royalties are estimated at $4290 million in Ohio, $247 million in Pennsylvania, and $406 million in New York.

S.009
(e) The first step in implementing the Reference Program would be the creation of a regulatory Task Force representing the three states and appropriate federal agencies. The Task Force would develop standard lease forms, drilling permit forms, and construction and operation permit forms. The Task Force would be responsible for recommending a minimum set of federal and state standards to guide offshore development activities. A single set of operating standards (rules and regulations governing drilling and casing procedures, drilling fluid programs, procedures for collecting and storing materials used and residuals generated, waste disposal, use of safety equipment, installation of wellheads and pipelines, etc.) is assumed to be adopted by each state that participates in the offshore development program. The Task Force could draw upon the expertise of the existing Interagency Study Group which is currently serving to support the entire environmental assessment process.

S.010
The Task Force would also draft the necessary enabling legislation to authorize offshore gas drilling and would create a standing review committee representing the three states and appropriate federal agencies to monitor administrative progress, maintain uniformity of the regulatory program, and communicate with state authorities about the program.

S.011
An integral part of the enabling legislation would be the creation of one office (the offshore progam office) in each state to manage the total program. Although various permitting authorities would remain in the state and federal offices, all requests, evaluations, and reviews would go through the offshore program office and this office would work jointly with the appropriate state and federal permitting offices in administrating the permit program. All review and monitoring of permit restrictions would remain the responsibility of the permitting agency.

S.012
(f) Alternatives

- Alternatives to the Proposed Action
  - Alternative Supplies of Natural Gas
    - Regional Land-Based Resources
    - Domestic Conventional Reserves
    - Domestic Unconventional Reserves
    - Imports of Foreign Gas
  - Alternatives That Extend Natural Gas Supplies
    - Low-Btu Coal Gasification
    - Medium-Btu Coal Gasification
    - High-Btu Coal Gasification
- Conservation, An Alternative That Reduces Demand
- Alternatives Within the Proposed Action
  - Modification of the Reference Program

S.013
(g) Disposal of Residuals--The materials used and residuals generated will be (wherever possible) collected, stored, and relegated to land disposal. The following residuals will be collected and brought to onshore treatment/disposal facilities: precompletion formation water, drilling fluids, deck drainage, completion fluid, spent acid, and stimulation returns. After phase separation in a settling pond, any oil and solid sludges will be removed to a landfill approved under the Resource Conservation and Recovery Act (RCRA). Treated liquids will be disposed of using onland spray-irrigation or other appropriate technologies. Drill cuttings, excess cement, and domestic waste will be transported to shore and disposed of in conventional landfills. Sanitary wastes will be transported to shore and treated in existing municipal waste-treatment facilities. Any formation water accompanying produced gas to shore in pipelines will be collected and reinjected into suitable onland, subsurface formations.

S.014
Some existing landfill sites are presently polluting groundwater and must be avoided. There would be low potential for additional groundwater degradation if wastes are disposed of in existing or new

settling ponds and/or landfills that are properly designed and constructed and that meet applicable criteria and regulations. If injection wells are properly developed in appropriate host formations sufficiently isolated from shallow freshwater aquifers, the risks of contamination would be low. Construction of new waste treatment/disposal facilities would preempt the further use of that land for wildlife habitat unless and until that land could be reclaimed. The total volume of land preempted is insignificant on a regional scale. To avoid environmentally sensitive areas, state-of-the-art suitability/constraint analysis techniques will be required to locate treatment/disposal facilities and any new landfills.

S.015
Conventional landfill sites are limited in the Lake Erie region, and sites for RCRA-approved landfills will be even more restricted. For disposal of sludges from onland waste treatment/disposal facilities, an alternative to using the few hazardous waste landfills in the region would be the use of onland dredged spoil disposal sites.

S.016
Disturbance of Toxic Sediments--Sediment resuspension is unavoidable during certain phases of the Reference Program. Sediment releases from program activities will be temporary; the disturbance sites will be dispersed throughout the U.S. waters of Lake Erie and isolated from water intakes, effluent outfalls, and environmentally sensitive areas by appropriate buffer zones. Impacts to water quality should be minor due to the localized and temporary nature of sediment resuspension.

S.017
Even though contaminanted sediments may be released, in deepwater activities the plankton community should be spatially isolated from the material since plankters are usually associated with surface waters and resuspension would occur near the lake bottom. During pipe-trenching activities in shallow nearshore areas, plankters could come into contact with resuspended sediments and the local plankton community could be impacted. Bioconcentration of toxic elements potentially contained in sediment could occur. However, considering the short duration of exposure, the small area affected, and the dispersion of resuspended material, significant adverse impacts are not expected.

S.018
Accidents--Releases of petroleum-related hydrocarbons, raw natural gas, and polyethylene glycol will occur only during accidents. The postulated accidents that produce these releases are loss of well control, rig or barge capsize, gas-line breakage, and glycol-line breakage. Occurrence of these accidents is highly unlikely. Although loss of well control would result in releases of petroleum-related hydrocarbons for periods of up to 15 days, the releases would be small and would impact localized areas. Hydrocarbon concentrations from releases should be dispersed to background concentrations fairly rapidly. A rig capsize, releasing diesel fuel, would also impact localized areas. Polyethylene glycols, released during a

glycol-line break, would not substantially impact water quality directly, although chlorination of these compounds in a potable water intake is a potential source of impact. The carcinogenicity and/or toxicity of the reaction between polyethylene glycols and aqueous chlorine is presently unknown.

S.019
If jack-up rigs, drillships, or stimulation barges capsize, numerous compounds would be released into Lake Erie. Potentially toxic compounds, such as chrome lignosulfonate, barite, and hydrogen sulfide, would be rapidly dispersed or removed from the water column by escaping into the atmosphere or by adsorption onto particulates and deposition on the lake bottom. Impacts to water quality would be minimal due to the localized and temporary nature of discharges from capsized vessels.

S.020
Accidental gaseous releases from an explosion and fire at a gas treatment plant or from the rupture of an 8-inch gas flowline could have a potentially deleterious effect on the general public. Combustion products resulting from an explosion and fire at a treatment plant include sulfur oxides, particulates, and hydrocarbons. Although the specific impact of this event on residents in the plant vicinity cannot be quantitatively assessed, it is expected that these residents would need to be evacuated. The rupture of a natural gas flowline, either onland or underwater, could result in the buildup of combustible gases and an explosion if an ignition source is nearby. For example, a ruptured 8-inch gas flowline could bubble gas to the Lake surface and, under worst-case dispersion assumptions, result in a potentially explosive cloud extending to the atmosphere. The area peripheral to this potentially explosive cloud would have to be identified and restricted from use by all boaters. The same event could occur with the rupture of onland gas flowlines and nearby residents would have to be evacuated. The rupture of an 8-inch flowline carrying H_2S gas would require the evacuation of all people within 500 m of the break to avoid the toxic effects of the gas. A larger area would probably be voluntarily evacuated by anyone in the area to avoid the annoying smell of the H_2S gas. Affected areas would need to remain evacuated until the release of gases from the leak could be stopped and until the potentially explosive and/or toxic gases had a chance to disperse.

S.021
(h) Several seismically active areas have been identified in the Lake Erie region; one of these is in northwestern Ohio where a northeast-trending cluster of earthquake epicenters has been recorded. A smaller cluster of epicenters exhibiting much less seismic frequency and earthquakes of no greater intensity than a Modified Mercalli (MM) scale of VI occurs in northeastern Ohio. A smaller, west-trending seismic area exists in western New York and Ontario; except for one high-intensity earthquake that occurred near Attica, New York (MM VIII), the intensity of earthquakes experienced in this region is generally low.

S.022
The overall frequency and intensity of seismic activity in the region is low and will probably not constrain Reference Program activities. In support of this conclusion, over 30 years of offshore drilling in Canadian waters of Lake Erie has not resulted in any documentable problems caused by seismic activity. According to Reference Program assumptions, earthquakes of intensity up to MM V or MM VI are expected to have little, if any, effect on offshore wells drilled and completed.

S.023
The Reference Program has been designed to minimize damage from lake ice to rigs, vessels, pipelines, and wellheads. The drilling season has been defined so that opening dates reflect average seasonal dates that ice clears from different sections of the Lake:

Open Drilling Season

New York:	May 1 - October 31 (184 days)
Pennsylvania:	April 1 - October 31 (214 days)
Ohio:	April 1 - October 31 (214 days)

S.024
Pipelines within the 30-ft water depth contour will be buried to a depth of between 5 and 10 ft to avoid damage from nearshore ice pileups. Wells will be prohibited from the nearshore area where damage from ice scour would be greatest. Deeper water wellheads will be placed below the water/sediment interface in cellars when drilled by jack-up rigs and where consolidated sediments will support a subsurface structure.

S.025
Despite the precautions taken to minimize ice contact with Reference Program structures, some accidents resulting from ice scour may still occur. Environmental impacts resulting from these accidents are not anticipated to be significant.

S.026
(i) Water Quality--The Reference Program is designed to limit discharges to the maximum extent practicable and to incorporate state-of-the-art technologies to protect water quality. Local, short-term degradation of water quality will result from rig placement and removal, well stimulation, underwater pipeline construction in the nearshore zone, removal of pipelines during decommissioning, and accidental releases of materials and residuals. Impacts to water quality from sediment resuspension and fluid releases should be minor due to the localized and temporary nature of the events.

S.027
Aquatic Ecology--Impacts to the aquatic biota of Lake Erie from Reference Program activities may occur either directly to an organism from the chemical and/or physical action of a discharge or indirectly from an activity that affects an organism by modifying its habitat or environment.

S.028
During pipe-trenching activities in shallow nearshore areas, plankters could come into contact with resuspended sediments and the local plankton community could be impacted. Bioconcentration of toxic elements potentially contained in sediment may occur. However, considering the short duration of exposure, the small area affected, and the dispersion of resuspended material, significant adverse impacts are not expected. Local, short-term losses of benthic habitat and aquatic organisms would be unavoidable. Organisms lost during construction activities will be replaced by natural reproduction and immigration from surrounding areas. Cumulative lakewide impacts to aquatic biota from the release of stimulation and decommissioning fluids in the course of seasonal drilling and over the period of time required to develop a lease area are expected to be minimal.

S.029
Reference Program activities could also disturb aquatic macrophyte communities. This disturbance would not be extensive areally and would be temporary. Recolonization of the disturbed area should occur rapidly.

S.030
Potable Water--Under Reference Program assumptions, drilling operations and underwater gas and glycol pipelines are excluded within 0.5 mile of a potable water intake. Concentrations of representative contaminants that may be released during an accident or through routine discharges have been estimated through a worst-case modeling analysis at the release point and at 0.5 mile from the release. At 0.5 mile from the point of release, concentrations of barium, chromium, chloride, and surfactants would be below maximum allowable contaminant levels; these concentrations should not be harmful in potable water supplies. The predicted concentration (0.1 mg/L) of hydrogen sulfide under equivalent conditions would exceed the maximum allowable concentration of 0.05 mg/L; it would produce an objectionable odor at 0.1 mg/L but would be oxidized by chlorine, forming free sulfur or dilute sulfuric acid. In the case of a pipeline break, di- or triethylene glycol may appear at potable water intakes at concentrations up to 1 mg/L. There are no drinking water standards for polymeric ethylene glycols. However, ambient level water quality goals for ethylene glycol have been set at 140 μg/L. Although the levels of polyethylene glycols from a pipeline break are relatively harmless, glycols can easily form chlorinated hydrocarbons. Because chlorinated hydrocarbons are known carcinogens, the direct chlorination of glycols at potable treatment plants is a potential threat to the consumer.

S.031
Should gas development in Lake Erie be found accpetable in principle, the above factors should be taken into consideration by water quality agencies when determining if further investigation of the products of reaction betwee aqueous chlorine and polyethylene glycol is warranted.

S.032
Land Use--Because of competition for limited coastal zone land and difficulties in gaining access to shore in areas of high bluffs, the siting of pipeline landfalls will be a problem. Public acceptance of landfalls may be strengthened by arranging for public access to the Lake along pipeline corridors. Use of pipeline rights-of-way by off-road vehicles can cause conflicts with use of private lands both on and adjacent to the rights-of-way.

S.033
Impacts associated with siting, construction, and operation of gas production facilities should be minimal due to the flexibility in siting these facilities away from the shoreline. State-of-the-art site suitability/constraint analysis techniques should be used to locate each pipeline landfall and gas production facility. Land and associated wildlife habitat will be lost to gas production facilities, onland pipeline corridors and waste treatment/disposal facilities unless and until that land is reclaimed to its original condition. When gas production facilities are abandoned, the land may remain in industrial use or it may change to some other use. Erosional degradation and/or removal of topsoil during construction could decrease the future agricultural potential of the site.

S.034
Noise from construction equipment, continual compressor operation, and annual underwater pipeline venting will be unavoidable. The degree to which this noise will cause adverse environmental impact is dependent upon the timing and nature of the noise, degree of control technology employed, characteristic surrounding land use, and physical features of the environment that can act to attenuate the noise as it travels away from its source.

S.035
Recreation--Impacts from Reference Program activities to recreational use of beach areas are expected to be slight. Increased commercial use of the Lake and its harbors could increase hazards to recreational boating. The presence of drilling rigs, service vessels, tugs, and barges in the Lake would slightly degrade the "open-sea" character of the Lake.

S.036
Ports, Shipping, and Navigation--The maximum number of vessels committed to the Reference Program includes eight drilling rigs, three stimulation barges, three pipe barges, eight service vessels, and three tow tugs. Existing port facilities in the Lake Erie region will be able to absorb peak vessel traffic increases attributable to the Reference Program. Because of their excellent port facilities, Buffalo, Erie, and Cleveland are likely candidates for development program harbors in New York, Pennsylvania, and Ohio waters, respectively. At least one more Ohio port probably would be used as a service center. Increased traffic due to natural gas development should have a temporary beneficial impact on Lake Erie port facilities.

S.037
Visual and audible warning devices should effectively reduce potential for collisions between rigs and vessels. Mariners will be advised where drilling rigs are and that they are equipped with audible and visual warning devices. The one-mile nearshore buffer zone should alleviate potential navigation congestion around harbors.

S.038
The likelihood of a gas well or pipeline being snagged and broken by an anchor appears minimal.

S.039
Cultural Resources--Reference Program activities that disturb the ground surface or subsurface can be potential sources of direct impacts to cultural resources. Indirect impacts may result from local residents and project personnel collecting, excavating, or otherwise disturbing cultural resource objects and sites.

S.040
Specific impacts of Reference Program activities are being determined as part of a multifaceted cultural resource study of Lake Erie and a one-mile area inland from the lakeshore. A predictive model will be constructed to identify the different potentials of select lease areas for containing cultural resources of various kinds and densities. At that time, it will be possible to make more realistic appraisals of the potential impacts at specific locations.

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CHAPTER ONE: PURPOSE, NEED, AND DESCRIPTION OF THE PROPOSED ACTION

PURPOSE AND NEED FOR THE PROPOSED ACTION

Introduction

1.001
Historically, relatively inexpensive and nationally plentiful supplies of clean-burning natural gas have led to wide-scale use of gas resources by industrial, commercial, and residential sectors in New York, Ohio, and Pennsylvania. Within the last decade, a combination of events--including regionally severe winters, inflation, a complicated gas-pricing structure, and institution of a complex gas-user priority designation--has resulted in periodic shortages of gas supplies to all three states. In an attempt to maintain local economies in the face of potential future curtailments and uncertainty concerning supply availability for large industrial gas consumers, each state has examined the potential for gas from new sources. All three states border Lake Erie and are aware that Canada successfully began developing and producing natural gas from beneath the lakebed in 1956 (although the first well was drilled in Canadian waters of Lake Erie in 1913).

1.002
Interest in developing gas resources in the U.S. portion of the central and eastern basins of Lake Erie has fluctuated over the past twenty years, depending on the balance of environmental, economic, and energy priorities. However, Lake Erie gas has never been viewed as the answer to natural gas supply problems by regional gas-user industries. In 1977, both New York and Pennsylvania lifted existing bans on offshore drilling. The Ohio legislature allowed the ban to expire in July 1978; Ohio policy concerning offshore gas development is currently a matter of legislative debate. By these actions, the states clearly indicated that they were willing to seriously explore the potential for developing U.S. Lake Erie gas resources. Regardless of the outcome of any state or federal initiative to establish a natural gas development program in Lake Erie, the International Joint Commission (IJC) has recommended the prohibition of drilling in the western basin ... "until such time as each of the Governments (U.S. and Canada) is satisfied that the containment and clean up methods and the contingency plans for oil spills applicable to the waters of Lake Erie within its jurisdiction are adequate" (Int. Joint Comm. 1970). Recognition of IJC policy, together with the maintenance of a strong Great Lakes preservation attitude, has resulted in the continuation of the drilling moratorium in Michigan's Lake Erie waters.

1.003
The Lake serves as a source of potable and industrial water. It is also used for recreation, commercial and sport fishing, shipping, and diluting waste effluents. Realizing the immeasurable importance of Lake Erie and the entire Great Lakes System, the United States and Canada initiated a concerted effort to reverse the intolerable deterioration of Lake Erie water quality caused by industrial, municipal, and agricultural wastes--a process that threatened the resource benefits prized by Canada, New York, Pennsylvania, Ohio, Michigan, and the entire United States. These efforts to improve Lake Erie water quality have required millions of dollars from state and federal budgets to restore and revitalize the Lake as an essential link in the Great Lakes

System, the world's largest body of surface fresh water. At all levels of government, any serious attempt to consider the development of U.S. Lake Erie natural gas has been tempered by the knowledge that, historically, the Lake's most essential resource value has centered on important uses other than energy production.

Definition of the Proposed Action

1.004
The U.S. Army Corps of Engineers (Corps) and the U.S. Environmental Protection Agency (USEPA) have both responded to state movement in the direction of offshore exploration by initiating preparation of a programmatic Environmental Impact Statement (EIS). The study was initiated through an Interagency Agreement between the Corps and USEPA in anticipation of applications for federal permits related to various gas development activities. This action will culminate in the issuance of a Final Environmental Impact Statement that will contain a comprehensive evaluation of the environmental acceptability of Lake Erie natural gas resource development.

1.005
The proposed action under consideration is the issuance of permits by the Corps and USEPA to lessees engaged in state-initiated development of offshore gas in Lake Erie. There is only one alternative (the no-action alternative) to this administrative action and that is the denial of all federal permits. In order to determine whether or not permits and, hence, an offshore program should be approved, a Reference Program is assumed and its environmental acceptability is evaluated. In the context of this analytical structure and resulting EIS, a lease sale conducted by one or any combination of states bordering the southern shore of Lake Erie--i.e., New York, Pennsylvania, and Ohio--has been postulated. Land would be leased to qualified parties or investors (operators). Since energy resource allocation is a free market, supply-demand process, natural gas produced from the Lake could either (1) be used directly by the operator, (2) sold to regional natural gas utilities for distribution to local gas consumers (residential, commercial, industrial), or (3) sold to regional natural gas utilities and piped out of the region for consumption in other parts of the country. Should the states proceed to conduct lease sales, potential operators would need federal permits prior to any development. Therefore, the proposed action is an evaluation of the impacts associated with federally permitted natural gas development in Lake Erie. To accomplish this evaluation, the analysis in this EIS is based on (1) postulated lease sales by the states as defined later in this statement and (2) a Reference Program that sets forth realistic assumptions for modes of operation, constraints, mitigation, restricted areas, waste handling, etc.

1.006
The ultimate action on a federal level is to determine if gas development can be accomplished in an environmentally acceptable manner in Lake Erie and, if so, under what circumstances. In this regard, the Reference Program described in this EIS contains both guidelines that could be used for federal approval and recommendations to the states for an administrative structure that could be acceptable. This EIS is also intended to gain input from the general public and federal, state, and local agencies and governments relative to environmental acceptability of U.S. Lake Erie gas development, as well as recommendations from these parties relative to Reference Program guidelines

and postulated lease sales. This input will be considered and, where appropriate, included in the programs. The final EIS will then set forth recommended minimum federal requirements and guidelines. The overall acceptability of U.S. Lake Erie gas development will be judged by the Corps and USEPA after the final EIS has been filed and the 30-day administrative waiting period mandated by the Council on Environmental Quality has expired. The program guidelines are summarized and cross-referenced in Appendix D.

Need to Postulate Purpose

1.007
It should be emphasized that this Draft EIS has been developed without the benefit of a project advocate. Consequently, there has been no tangible proposal submitted for analysis; yet, a specific program detailing engineering design, activity timing, and administrative structure is required before risks (environmental impacts) can be assessed. Realistic assumptions describing the structure and function of a possible three-state natural gas development program for Lake Erie are developed throughout this chapter.

1.008
New Council on Environmental Quality regulations for EIS preparation emphasize the importance of identifying and comparing alternatives to the proposed action. A prerequisite for this comparison is a clear definition of the purpose and need for the proposed action. Since the Corps and the USEPA have regulatory jurisdiction over activities affecting the environment and do not have jurisdiction over mineral resource development, it has been necessary to hypothesize purpose and need in order to evaluate the performance of the proposed action and alternatives.

Description of Purpose and Need

Demand for Natural Gas by Regional Industrial Gas Consumers

1.009
The region bordering the southern shore of Lake Erie is a national industrial center and a net importer of energy resources, including natural gas. Lake Erie regional industry (e.g., primary metals; stone, clay, glass, and concrete; and chemicals and allied products) relies on natural gas for process heat and chemical feedstock (see Chapter Three - Regional Economy, Industrial Natural Gas Consumption). Natural gas used for process heat is burned in furnaces, kilns, or heaters for (1) heating, melting, and treating in the primary metals industry; (2) transforming feedstock in the chemicals and petroleum refining industries; and (3) calcining, drying, and melting in the stone, clay, and glass industry (Lerner 1980). In chemical feedstock industries, natural gas is used as a raw material for the production of fertilizer, chemicals, or other products.

1.010
The Energy Policy and Conservation Act (EPCA) of 1975 (Pub. L. 94-163, 42 USC §§ 6201 et. seq.) is one of the major building blocks serving to form contemporary policy on energy use and conservation in the United States. Among the many stated purposes of EPCA are the following:

> To increase the supply of fossil fuels in the United States, through price incentives and production requirements.

To conserve energy supplies through energy conservation programs, and, where necessary, to regulate certain energy uses.

To reduce the demand for petroleum products and natural gas through programs designed to provide greater availability and use of this nation's abundant coal resources.

1.011
Under EPCA guidelines, an already existing Voluntary Industrial Energy Conservation Program was revised. Major energy-consuming industries, for which industrial energy efficiency improvement targets have been set by the Federal Energy Administration (FEA), are now required to report to the FEA on progress made in achieving the stated targets. Targets have been established for all three categories of natural gas consumers important in the Lake Erie region (U.S. Dep. Energy 1979). Efficiency targets are subject to periodic revisions.

1.012
Another significant piece of federal legislation, i.e., the Powerplant and Industrial Fuel Use Act of 1978 (FUA), reemphasizes the need for U.S. industries to switch from oil and gas to more plentiful domestic hydrocarbon fuels such as coal. Although FUA gives the U.S. Department of Energy (DOE) the authority to prohibit the use of oil and gas as primary fuels in existing powerplants and major fuel-burning installations, the law allows for consideration of exemptions on a case-by-case basis; FUA also excludes those consumers of natural gas not explicitly defined as powerplants, boilers, gas turbine units, combined cycle units, or internal combustion engines. Consequently, although representative industries in the Lake Erie region are required to decrease demand for gas through implementation of conservation procedures, they are not categorically prohibited from burning natural gas when it is used in furnaces, kilns, heaters, or as feedstock for manufacture of other products. There is significant evidence pointing to a continued long-term need for natural gas in the above Lake Erie industries, based on technical constraints in converting to alternative fuels such as coal. "Direct use of coal is a proven technology for only a small portion of the gas and oil currently consumed in process heat equipment. . . . Some of the specific factors that limit the feasibility of coal use in process heat applications include burner size, heat distribution requirements, and fuel contaminants. . . . Due to uncertainties regarding the technical feasibility, costs, and rate of acceptance by industry, . . . direct coal use in process heat applications will not reduce significantly oil and gas use until at least 1990" (Lerner 1980).

1.013
Of course, for process heat and chemical feedstock purposes, the potential exists for the use of synthetic gas derived from coal instead of natural gas. Unfortunately, gasification plants are expensive and lead times for development of these large-scale technologies will be into the late 1980s (Lerner 1980). A thorough evaluation of the potential for synthetic gas for regional use is presented in Chapter Two - Alternatives That Extend Natural Gas Supplies.

Disparities Between Natural Gas Supply and Demand

1.014
Gas utilities contract with transmission companies for long-term supplies based on projected demand. Under previously existing federal price ceilings

for interstate gas sales, and given a situation where demand for natural gas was great, suppliers could receive higher prices for their gas when sold within the producing state. In the event of supply shortages, suppliers would not be willing to commit reserves to the interstate market when potential revenues from intrastate sales would be higher. For example, during the severe winter of 1976-1977 in the Lake Erie region, supply shortages were caused by an abnormally high demand for gas along with regional industrial dependence on natural gas and interstate pricing regulations. The Federal Energy Regulatory Commission (FERC) imposed usage curtailments on industrial gas users; these curtailments resulted in plant closings and employee layoffs. Strong political response to these layoffs encouraged state consideration of regional gas development, i.e., supplies not subject to interstate price regulation. It was hoped that increased regional supplies would help buffer future shortages caused by the reluctance of interstate suppliers to pipe gas to the region at depressed, regulated prices. Offshore natural gas development in Lake Erie was postulated as one mechanism to decrease potential curtailments to regional industrial users of natural gas; this would be accomplished by augmenting regional gas supplies with intrastate reserves not subject to federal price regulations.

1.015
The Natural Gas Policy Act (NGPA) of 1978 eliminated the distinction between the interstate and intrastate price of new gas. Elimination of price regulations is expected to have a positive effect on natural gas supply availability nationwide. Also, elimination of interstate price regulations will decrease the reluctance of operators in traditional producing states (Texas and Louisiana) to sell gas to the Lake Erie region in the event of future shortages.

1.016
From a post-NGPA perspective, Lake Erie natural gas development must be analyzed in terms of a different purpose and need than originally postulated.

Statement of Purpose

1.017
For this EIS, the impetus for development of Lake Erie natural gas will be defined as an attempt by New York, Pennsylvania and Ohio to provide a more secure regional natural gas reserve base; this regional reserve base will provide flexibility in supply sources for gas utilities and large industrial gas users in the event of future gas deliverability problems. This supply flexibility will possibly ensure the continued availability of natural gas to large industrial gas users.

1.018
Energy is emerging as a major locational factor for U.S. industries. From their perspective, it is important that adequate sources of energy be available on an uninterrupted basis. A perception of plentiful and sustained energy supply is an important prerequisite for regional industrial stability and growth. Industries are only likely to maintain or expand future production capacity in regions that are perceived to have adequate energy resource supplies. In the heavily industrialized, gas-intensive Lake Erie region, the development of supplemental and flexible sources of gas to augment traditional supplies could be a major factor in maintaining industrial economic viability.

1.019
It is important to emphasize that an investigation of the need for U.S. Lake Erie natural gas is entirely independent from an investigation of the environmental acceptability of an assumed offshore gas development program. To fully explore the need for U.S. Lake Erie gas would require a comprehensive study of regional and national fuel supplies (coal, electricity, natural gas, oil, renewable fuel resources), predicted trends in fuel imports and exports, and forecasted end-user energy demands by sector (commercial, industrial, residential, transportation). Such a study would be highly sensitive to assumptions concerning international politics, inflation, government energy policies and regulations, and private market investment capability. It is a sufficient argument to point out that the need for U.S. Lake Erie natural gas has varied greatly over the past 30 years depending on the conditions listed above and upon the perspective from which the problem is viewed--e.g., gas-user industries, state and federal energy or environmental regulatory agencies, public environmental conservation groups, energy development industry. Consequently, the determination of need for U.S. Lake Erie gas is best relegated to the political arena. This document will concentrate on an investigation of whether or not U.S. Lake Erie natural gas can be developed in an environmentally acceptable manner, assuming recognized need.

DESCRIPTION OF THE PROPOSED ACTION

Introduction to the Reference Program Concept

1.020
Interest by the Corps and the USEPA in evaluating benefits and impacts of U.S. Lake Erie natural gas development has preceded initiation of state leasing programs and formal requests by industry operators to drill in the Lake. Yet, without an engineering program outlining the nature and timing of activities, and requirements for offshore drilling rigs, service vessels, and onshore production facilities, it would be impossible to analyze potential impacts caused by routine and accidental discharges, emissions, and wastes. In the absence of engineering, cost, and personnel data, and activity timing information, a hypothetical Reference Program was developed as a means of identifying necessary conditions for impact assessment. This Reference Program was not developed as a prediction of future events but rather as a set of operational assumptions frozen in time for analysis purposes. All program assumptions were created to be realistic and to make it possible for appropriate decision-makers to answer one question: can U.S. Lake Erie natural gas be developed in an environmentally acceptable manner. The standard for determination of environmental acceptability is defined by existing laws, regulations, and standards for protection of potable water, fish and wildlife, and recreational, esthetic, land use, water use, and other values of the Lake and its watershed.*

1.021
The number of potential programs that could be suggested for assessment is virtually limitless. Each program would have a specific set of assumptions

*Throughout this Environmental Impact Statement, the environmental laws, regulations, and standards used as a measure of environmental acceptability will be identified.

concerning state rules and regulations for offshore gas developers, lease requirements, operator investment strategies, number of potential operators, activity timing, material and labor costs, gas prices, and many other factors. Since environmental acceptability is a significant concern and the analysis is based on only one set of program assumptions, it is necessary to postulate implementation of the most protective technologies currently available for developing and producing natural gas from Lake Erie. This program would result in the smallest possible release to the environment of materials used and residuals generated and consequently minimize environmental damage within available technological limits. If this Reference Program cannot pass a test of environmental acceptability, then offshore U.S. Lake Erie natural gas development must be rejected in principle.* Such a program will be presented throughout this impact statement. It will be discussed and evaluated as if it were a real program proposed by an industry operator in the course of applying for all appropriate permits.

Definition of the Reference Program Study Region

1.022
Earlier phases of the overall U.S. Lake Erie natural gas development assessment, i.e., the scoping process and field research projects as outlined in the Phase I Report (McGregor et al. 1978), have been based on a study region that corresponds to the U.S. waters of Lake Erie east of a line drawn between Marblehead, Ohio, and Pt. Pelee, Ontario (Figure 1-1, map pocket); the land areas included in this offshore portion of the Reference Program Study Region are presented in Table 1-1. Since only natural gas is being considered for development in the Reference Program, the western basin of the Lake was deliberately deleted from the study region to eliminate the greater possibility of encountering oil reservoirs. This reasoning evolves from the United States' intentions to comply with an International Joint Commission recommendation (Int. Joint Comm. 1970) to prohibit any drilling in the western basin and development of oil and wet gas containing appreciable amounts of liquid hydrocarbons anywhere in the Lake until the United States and Canada are satisfied "that the containment and cleanup methods and the contingency plans for oil spills . . . are adequate."

1.023
Ten counties bordering the southern shore of the Lake (Figure 1-2) have also been included in the study region so that inland impacts from offshore and onshore activities could be analyzed and presented. The terrestrial portion of the Reference Program Study Region was limited to these ten counties in order to concentrate assessment efforts in those areas where development and production activities would have direct environmental consequences.

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*If the Reference Program is judged acceptable, it could be used as a guideline. Specific proposals of future applicants could be weighed and balanced against the Reference Program. Future program proposals that vary significantly from the Reference Program and constitute relaxed technological performance standards could be evaluated on a case-by-case basis to determine the consequences of allowing increasing amounts of materials and residuals to enter the environment.

Table 1-1. Total Offshore Land Areas Beneath State Waters in the Reference Program Study Region

State	Land Area (acres)	Land Area (mi^2)	Percent of Total
New York	374,000	584	13.8
Pennsylvania	466,000	728	17.2
Ohio	1,870,000	2,920	69.0
Total	2,710,000	4,232	100.0

1.024
An Onland Alternative Program was created as a mechanism for the reader to compare offshore gas development impacts to an onland program of similar magnitude, areal coverage, and timing. This comparative structure was intended to demonstrate relative advantages and disadvantages of implementing an equivalent program in an aquatic and terrestrial environment. The Onland Alternative Program is not offered as a formal development alternative to the Reference Program, i.e., it is not fabricated to the same level of detail because it is not expected to be chosen in preference to the Reference Program. The Onland Alternative Program is presented to allow the reader to examine the Reference Program from a more comprehensive and perhaps more familiar vantage point. Based on a strict definition of the proposed action as the issuance of permits related to various development activities, the only administrative alternative to acceptance of the Reference Program would be denial of permits consequent to conceptual disapproval of offshore development, in principle, based on environmental criteria.

1.025
In order to compare impacts resulting from an alternative program for developing regional gas supplies against offshore Reference Program impacts, a 23-county Onland Alternative Study Region was created. This enlarged onshore study region (see Figure 1-2) expanded the inland boundaries of the Reference Program Study Region to include those areas where onland exploration could prove the existence of gas resources that could provide an immediate alternative to offshore drilling.

Assumptions Leading to Definition of the Reference Program

Physical Properties of Gas-Bearing Target Formations

Geology

1.026
As natural gas is the resource of interest in the Reference Program, its location, mode of occurrence, and confinement in economically recoverable reserves are of primary importance. Inasmuch as there is very little data on gas occurrence beneath the U.S. Lake Erie, one must rely initially on indirect evidence such as geological and production data generated in areas presently being exploited for natural gas in and around Lake Erie.

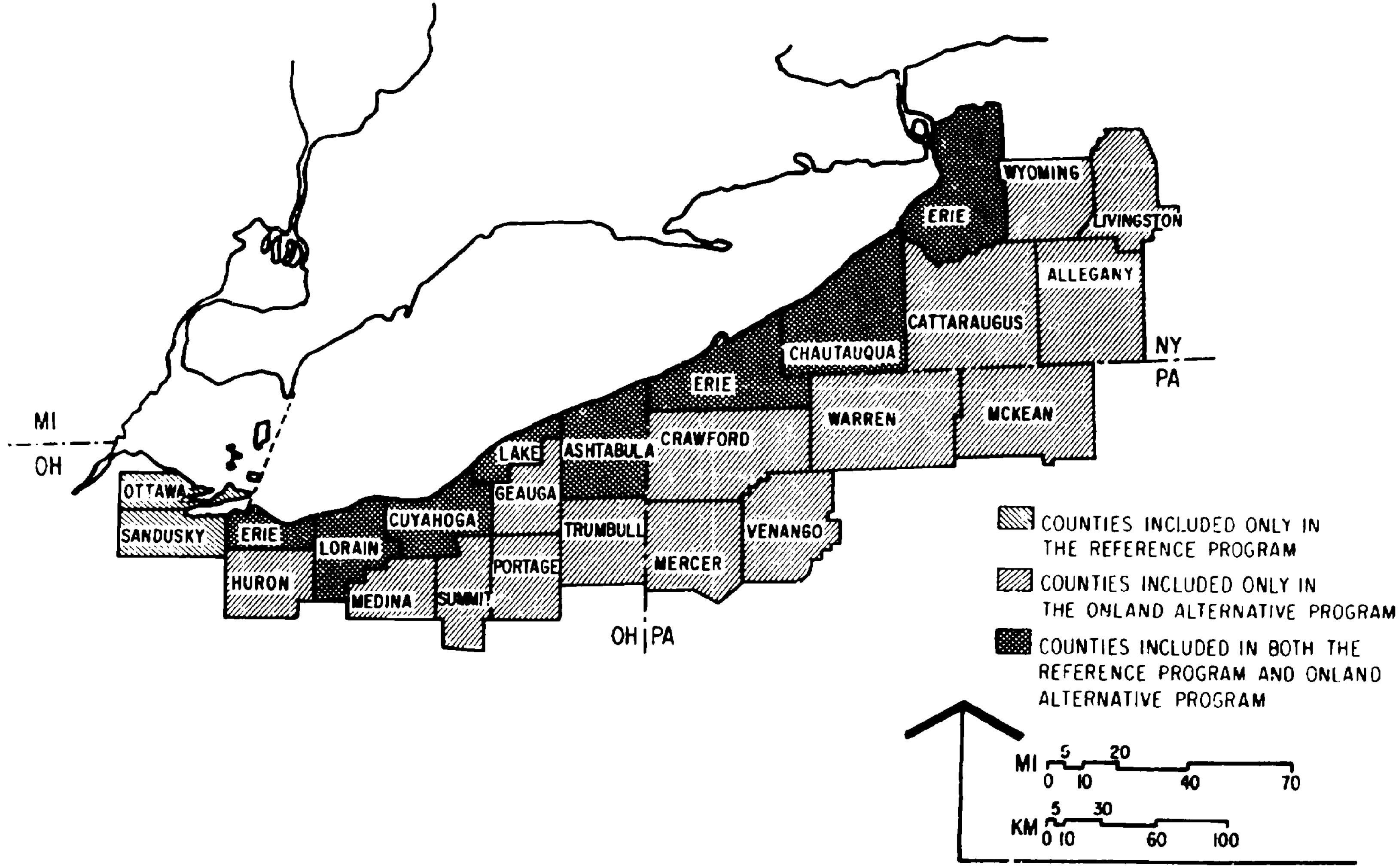

Figure 1-2. Counties in the Lake Erie Region Used to Delineate the Reference Program Study Region and the Onland Alternative Study Region.

1.027
Numerous published geological studies have led to the generally accepted conclusion that gas-bearing formations underlie U.S. Lake Erie as indicated in a summary overview of the Lake Erie region geology (McGregor et al. 1978). Figure 1-3 is a geologic map of the Lake Erie basin and surrounding area. Additional geologic, paleogeographic, and reservoir formation data are included in the following references: Clifford 1975; Lawler Matusky & Skelly 1977; Bulmer and Bulmer 1972; Eardley 1951; Janssens 1977; Mesolella 1978; Pennsylvania Department of Health 1968; Knight 1969; Smosna and Patchen 1978; and Shafer 1977; these data are summarized in the following discussion.

1.028
The northern Ohio, southern Ontario region is part of the periphery of a small topographic subbasin (the "Ohio" basin) of the Appalachian basin. The "Ohio" basin is separated from the much larger Michigan basin to the north by structural arches (Findlay and Algonquin arches); except for a low area (the Chatham sag), these arches form an arcuate northern boundary for the "Ohio" basin. From the apex of this basin rim, centered near the northern shore of Lake Erie (opposite Lorain, Ohio), the geologic strata exhibit a general southeasterly dip.

1.029
The gas-producing formations of primary interest in the Reference Program are the Lower Silurian Clinton-Medina (Clinton-Cataract) sandstones and Middle Silurian Lockport Formation biohermal reef structures (Clifford 1975; Bulmer and Bulmer 1972; Lawler Matusky & Skelly 1977; Shafer 1977). Figure 1-4 is a generalized correlative stratigraphic section across the Lake Erie area, derived from drillers' logs. Figure 1-5 is a cross-section based on gamma-ray logs of wells from north-central Ohio to southwestern New York. These figures indicate that the producing formations are present at the lake's edge and that they do indeed extend beneath U.S. Lake Erie (as also suggested in the references cited above).

1.030
Figure 1-6 shows the paleogeographic patterns of the Lower and Middle Silurian deposits in the adjacent areas of Ohio, Pennsylvania, and New York. This figure depicts the location of the gas- and oil-bearing Medina sandstones and the Middle Silurian basin, including potential gas-producing reef structures in the Lake Erie region. Figure 1-7 is an isopach map of the Silurian-Devonian carbonate sequence in north-central and northeastern Ohio; it also shows the regional extent of Upper Silurian salt deposits.

1.031
Natural gas is being produced from these formations in the Lake on the Ontario side (Hurd and Kingston 1978) and on land both north and south of the Lake (Clifford 1975; Ontario Ministry of Natural Resources 1978). Figure 1-8 is a map of natural gas fields in the Lake Erie region including the Ontario side of Lake Erie.

1.032
Clinton-Medina sandstones, mapped across the eastern half of Lake Erie (Figure 1-6), have been and are yielding abundant gas to wells (Clifford 1975). Within the broad band of deltaic sandstones that make up the Clinton-Medina

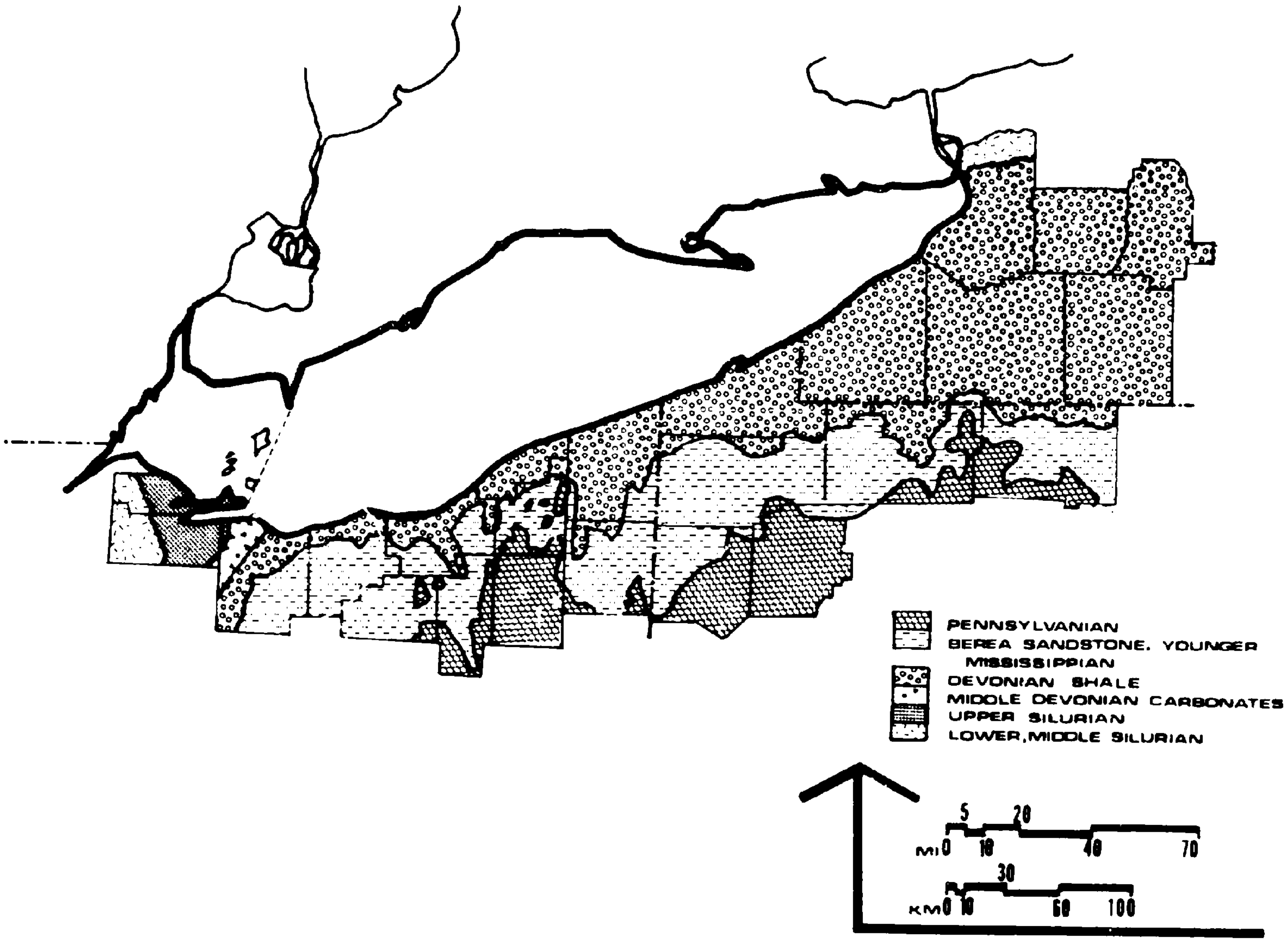

Figure 1-3. Geologic Map of the Lake Erie Region.

FEASIBILITY STUDY FINAL REPORT
OHIO LAKE ERIE NATURAL GAS EXPLORATION & DEVELOPMENT
SHAFER EXPLORATION CO INC, COL, OH SEPTEMBER 1, 1977

OHIO ENERGY & RESOURCE DEVELOPMENT AGENCY
CONTRACT 77 15 JUNE 1, 1977

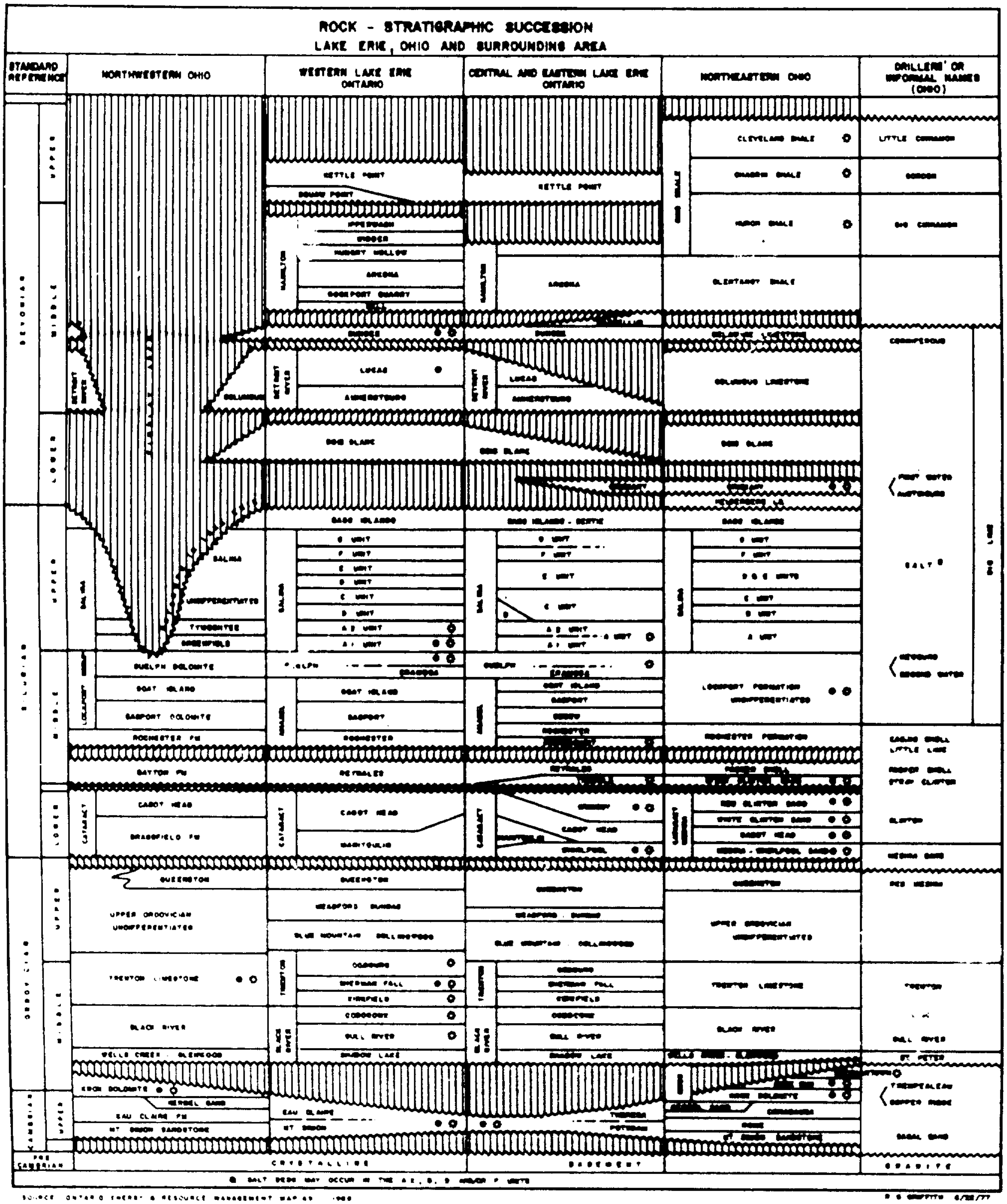

Figure 1-4. Generalized Correlative Stratigraphic Section Across the Lake Erie Area Derived from Drillers' Logs. From Shafer (1977) (with permission).

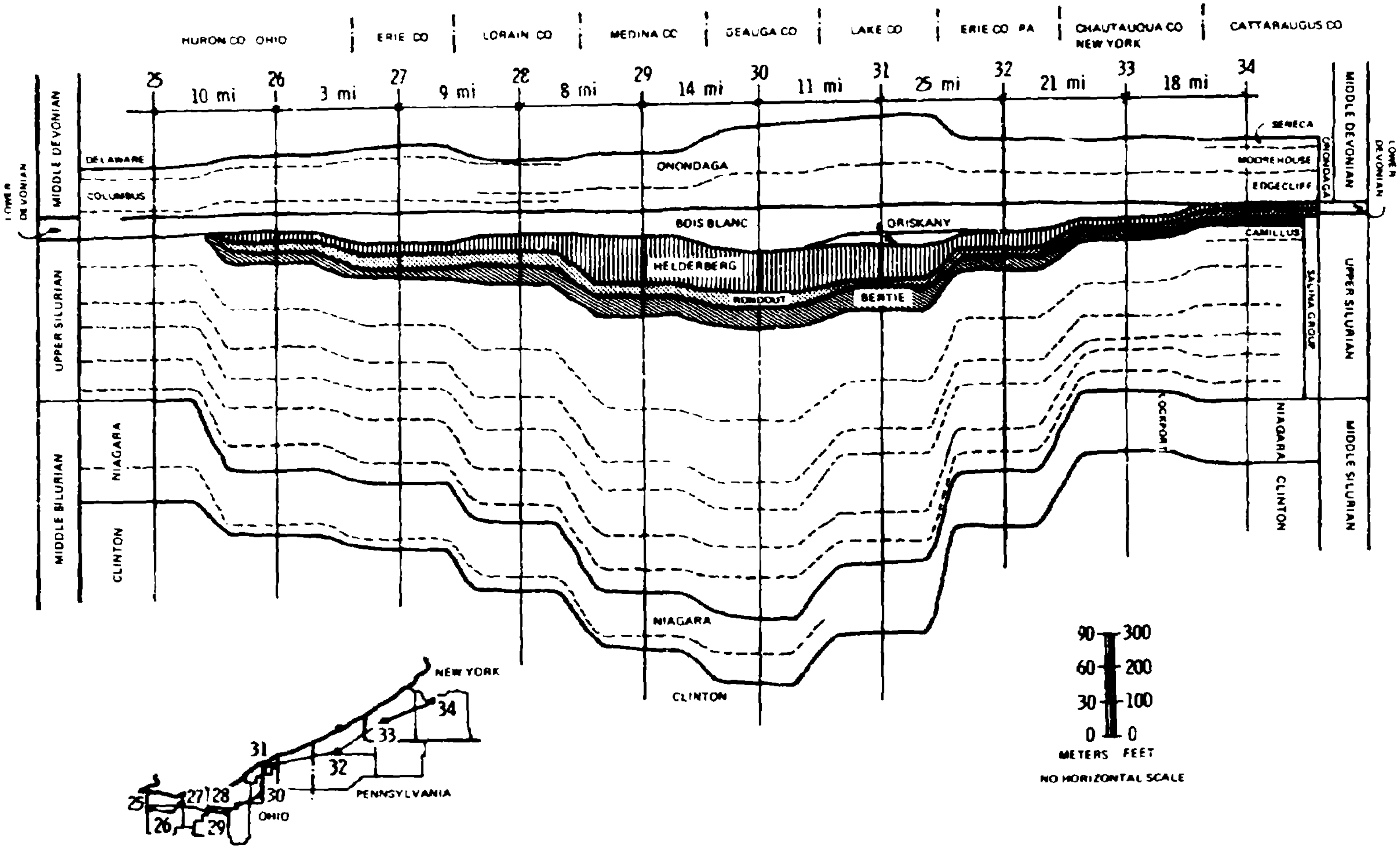

Figure 1-5. Cross Section from Southwestern New York to Northern Ohio Based on Gamma-Ray Logs. Adapted from Mesolella (1978) (with permission of the American Association of Petroleum Geologists).

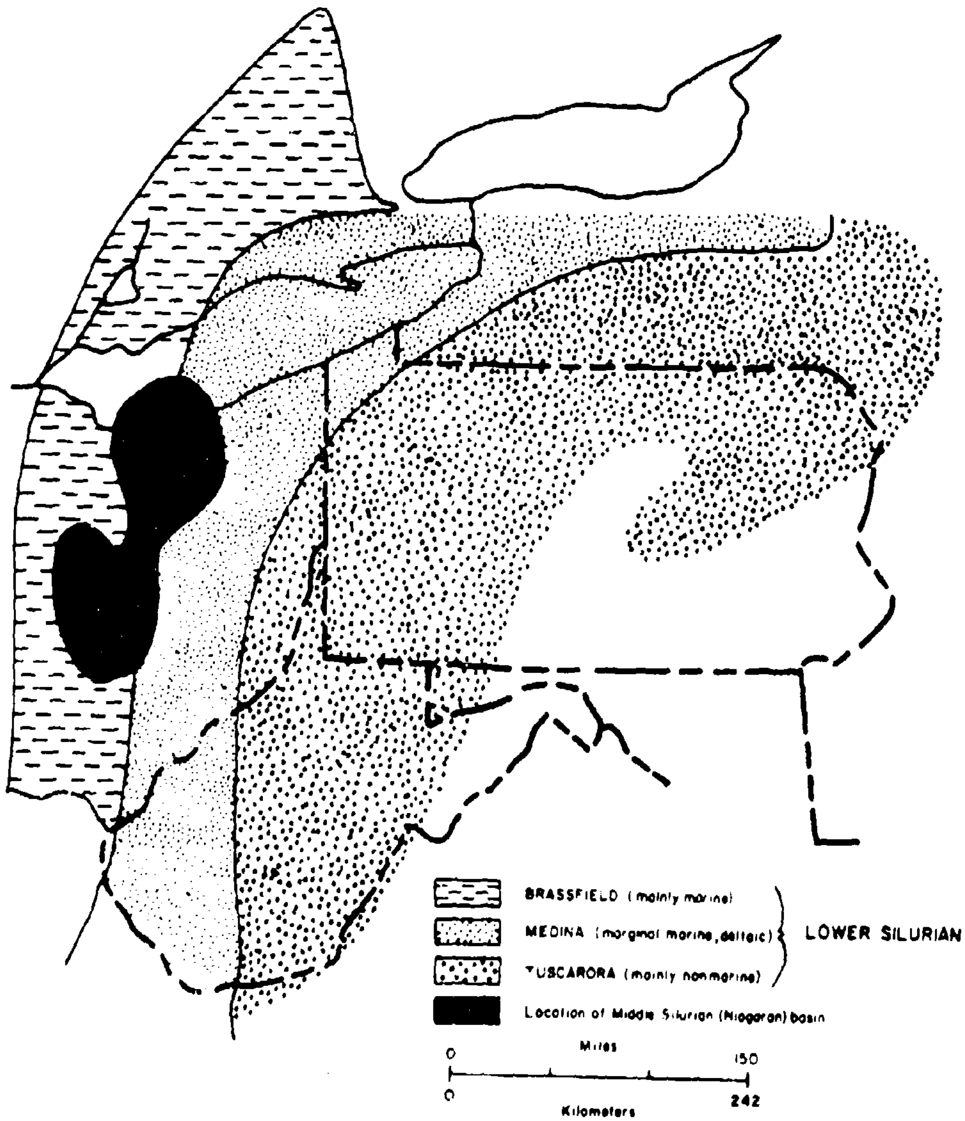

Figure 1-6. Comparison of Lower and Middle Silurian Paleogeographic Patterns in the Appalachian Basin. From Mesolella (1978) (with permission of the American Association of Petroleum Geologists).

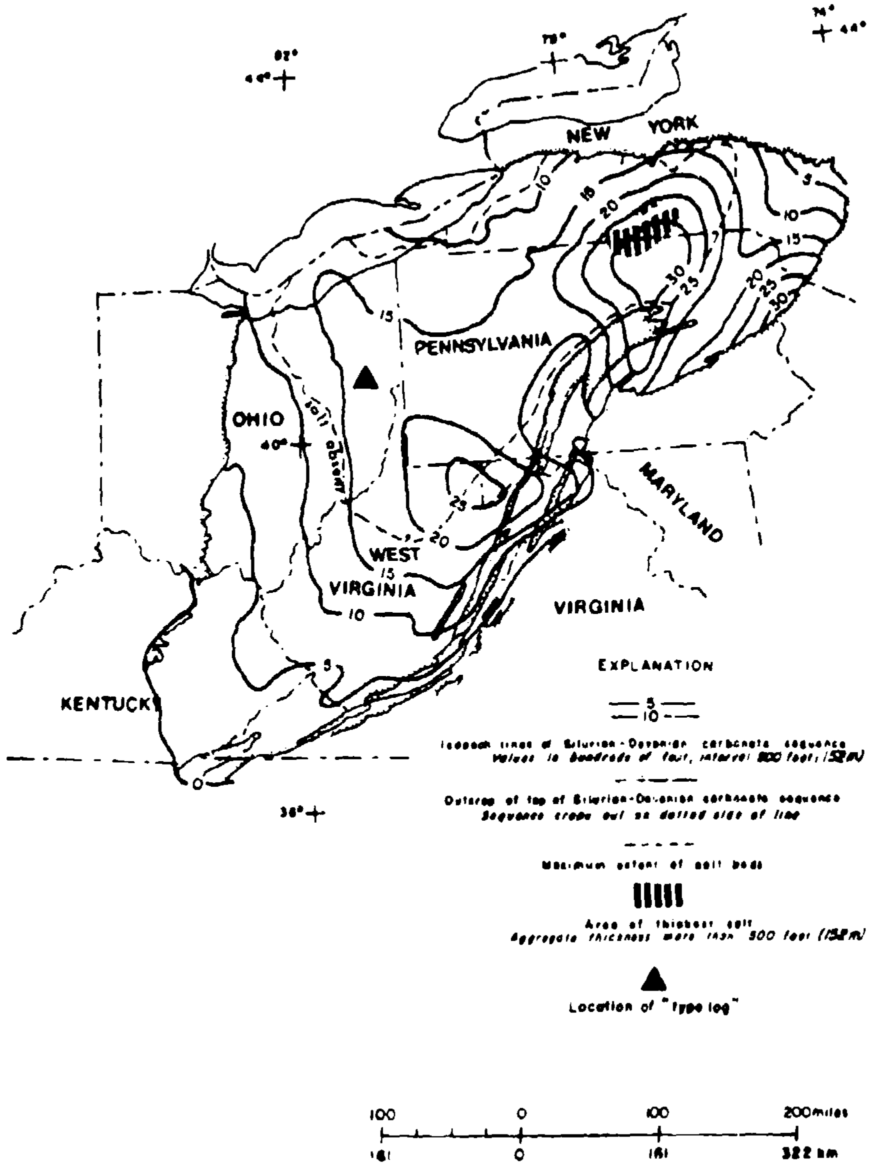

Figure 1-7. Location and Thickness of Silurian-Devonian Carbonate Sequence, Appalachian Basin. From Mesolella (1978) (with permission of the American Association of Petroleum Geologists).

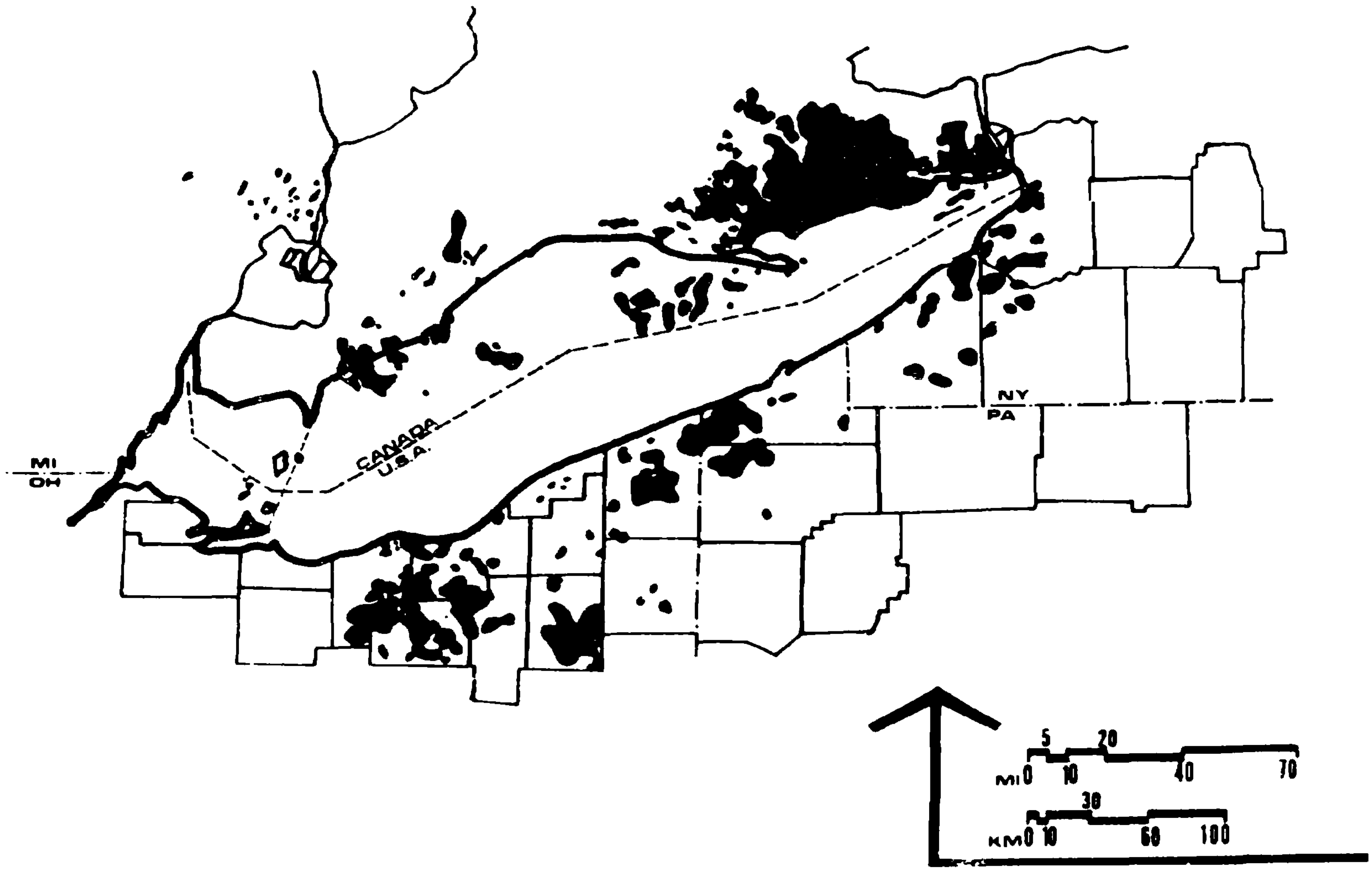

Figure 1-8. Silurian Gas Fields in the Lake Erie Region. Adapted from DeBrosse and Vohwinkel (1974), Lytle and Balogh (1977), and New York Department of Environmental Conservation (1977).

formations, abundant gas is expected from wells in central and eastern Lake Erie (Lawler Matusky & Skelly 1977; Townsend 1970; Bulmer and Bulmer 1972).

1.033
The Middle Silurian Lockport Formation reef structures [notable production (pay) zones] are more widely scattered and their locations are not easily predicted (Clifford 1975; Mesolella 1978). Figure 1-9 is a reconstruction of the Middle Silurian paleogeography of the central Great Lakes region. This figure shows the distinct "Ohio" basin, the approximate locations of pinnacle reefs in the basin, and the extension of the basin beneath Lake Erie in north-central Ohio. Figure 1-10 is an isopach map of the Silurian Lockport Formation and A_1 anhydrite in the "Ohio" basin. Also indicated are approximate locations of pinnacle reefs and the A_1 anhydrite and possible "Newburg" (very productive) zones. Average patch reefs are 25 ft high and up to 100 ft in diameter (Crowley 1973).

1.034
After study and analysis of these data, a scenario of gas production from both the Clinton-Medina sandstones and the Lockport Formation in the U.S. Lake Erie was synthesized. As indicated above, the Clinton-Medina sandstones form a blanket deposit that underlies the central and eastern lake basins and will likely produce gas throughout its extent. The Lockport Formation is also extensive beneath the Lake; however, only reef structures and/or "Newburg" zones are known to produce gas.

1.035
Figure 1-1 (map pocket) is an illustration of assumed locations of gas-producing formations beneath the U.S. waters of Lake Erie. The map is based on available published and unpublished data on region-wide geology, paleogeography, gas exploration and production well logs, and historical gas production statistics for both the Clinton-Medina sandstones and the Lockport Formation. In order to provide a set of realistic assumptions for environmental impact analysis, gas-bearing Lockport reefs were postulated to exist in Ohio waters of the Reference Program Study Region. Interpolation of unpublished Lake Erie seismic data provided the basis for generally identifying the potential location and size of Silurian reefal structures. It is believed that although the reefs are large in Ohio waters, they will decrease in size to the east. Confirmation of the presence of gas-bearing structures in U.S. waters of Lake Erie would require industry purchase and interpretation of existing seismic data or collection and interpretation of new data in addition to on-structure exploratory drilling.

1.036
It should also be noted that Figure 1-1 (map pocket) is interpretive and that not all seemingly favorable production sites or structures will actually produce economical quantities of gas and that it will be necessary for operators to further define the target zones and/or structures in the event of program approval.

Reservoir Characteristics

1.037
Known reservoirs containing typical producing zones were studied in order to provide a basis for estimating those characteristics that are expected in U.S.

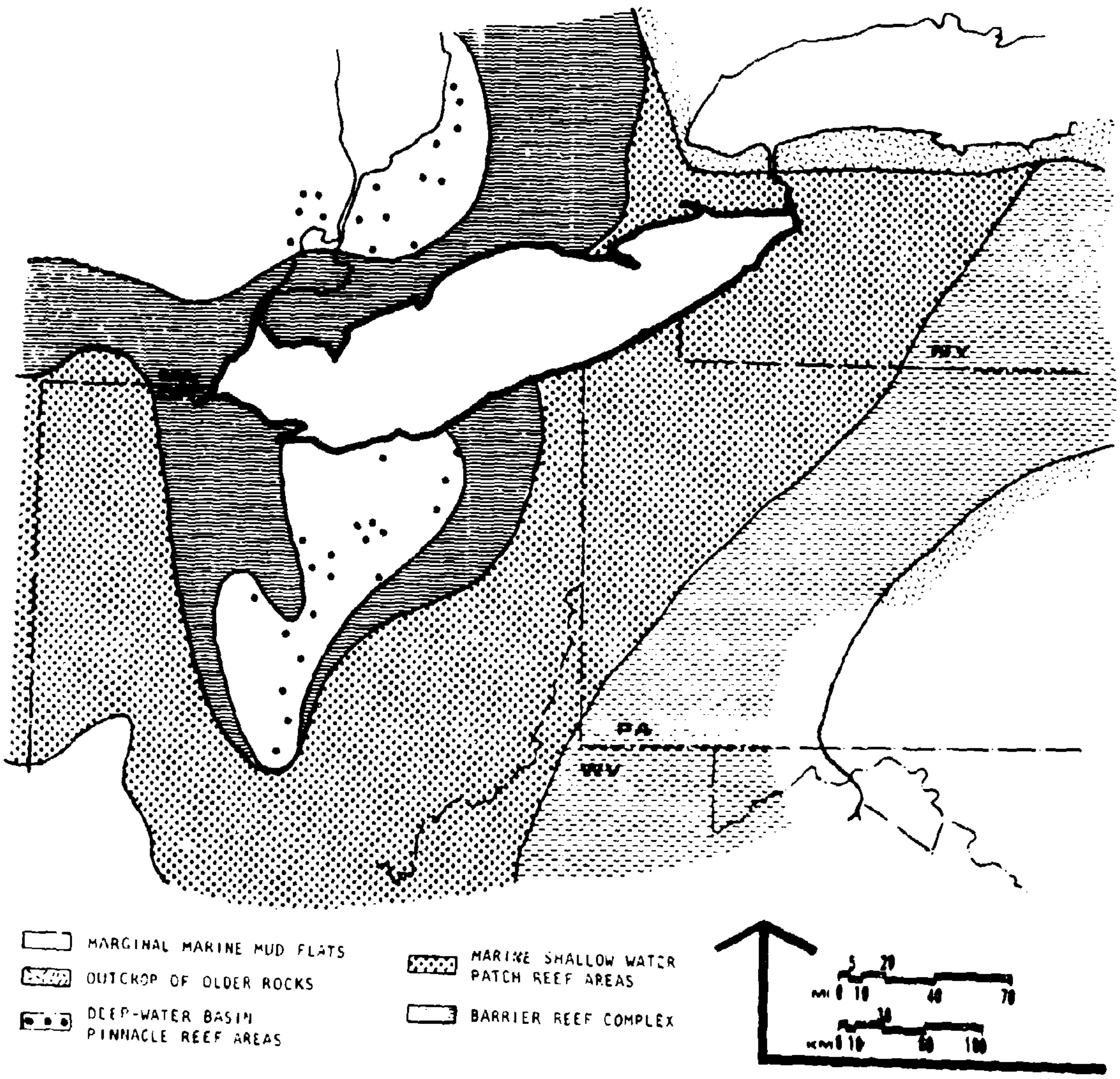

Figure 1-9. Middle Silurian Paleogeographic Reconstruction of the Great Lakes Region. Adapted from Mesolella (1978) (with permission of the American Association of Petroleum Geologists).

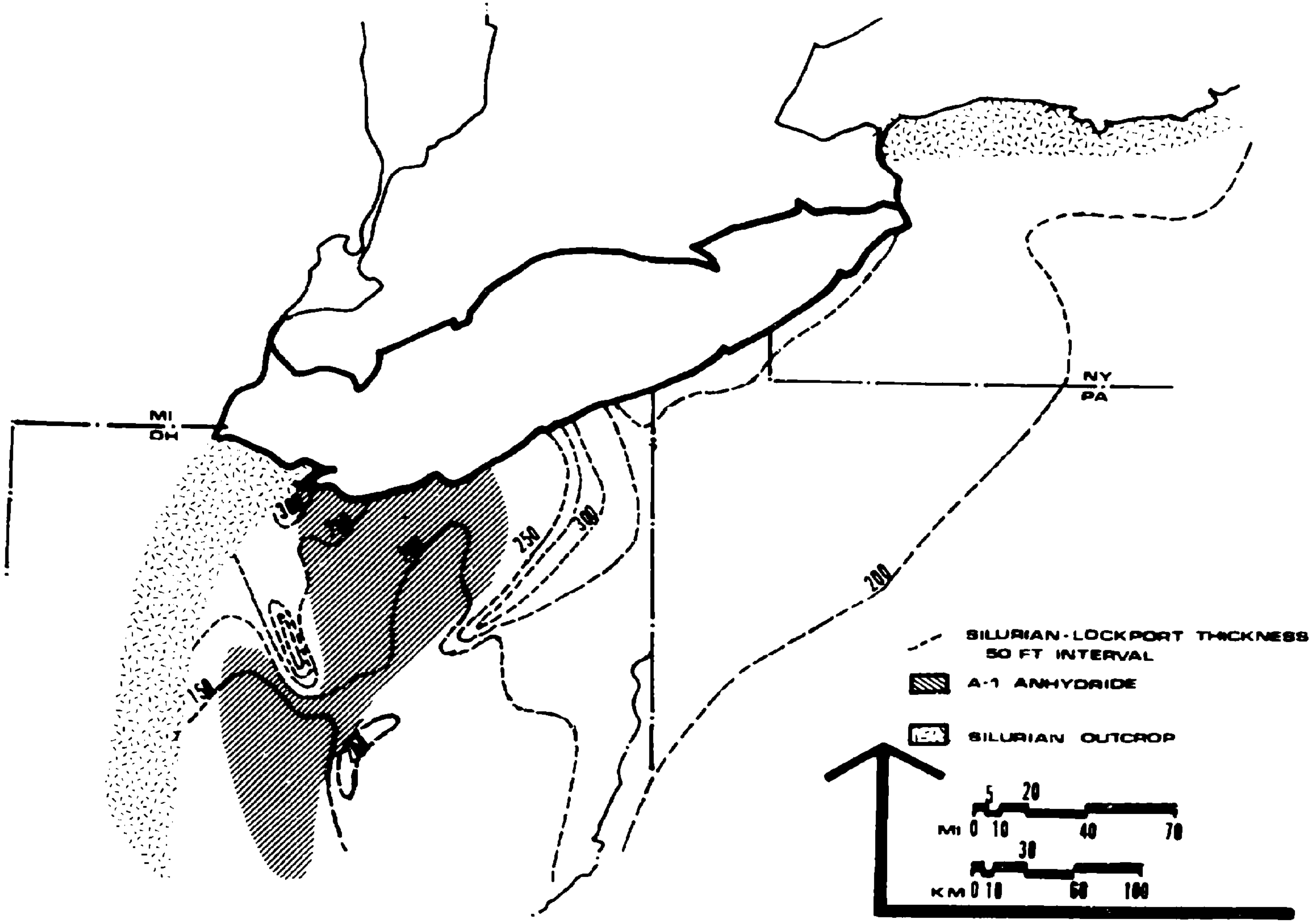

Figure 1-10. Silurian-Lockport (Niagara and A-1) Thicknesses Showing Position of Topographic Basin in Ohio. Adapted from Mesolella (1978) (with permission of the American Association of Petroleum Geologists).

Lake Erie. Much of the reservoir data is contained in government records of well registration and published reports or was gathered through informal discussions with geologists and operators representing the region's gas industry. Most of these data reflect land drilling experience. However, some offshore Canadian Lake Erie data were available through Canadian government reports. Table 1-2 is a compilation of anticipated reservoir characteristics expected in the Reference Program Study Region.

1.038
Natural gas reservoirs can function in two fundamental ways with respect to the phase of produced materials. Reservoirs in which gases behave as condensate (retrograde) gases, or wet gases, can result in the production of natural

Table 1-2. Reservoir Characteristics Expected in the Reference Program Study Region

Reservoir Characteristic	Formation: Clinton-Medina	Formation: Lockport
Stratigraphic trap	Porous deltaic sediments capped by less permeable barrier units confining gas in pore spaces	Zones of high porosity (dolomitized reefs) capped by the A_1 anhydrite (e.g., "Newburg" zones)
Structural trap	--	Scattered, biohermal patch and pinnacle reefs; and large barrier reef complexes
Porosity	9-12%	10-12%
Permeability	2-25 millidarcies	Highly variable
Connate water (free formation water) as a percent of pore saturation	20%	35%
Total gas in place	0.73 BCF/mi^2	1.4 BCF/mi^2
Representative hydrocarbon components as a fraction of total gas (mole percent)[a]		
C_1	88.06	84.50
C_2	4.77	4.97
C_3	1.24	1.41
i-C_4	0.21	0.22
n-C_4	0.22	0.31
i-C_5	0.04	0.06
n-C_5	0.03	0.06
C_6 (plus)	0.01	0.03
Gas molecular weight	17.36	17.58
Gas specific gravity	0.65	0.65
Condensate molecular weight	83.44	90.35
Condensate specific gravity	0.80-0.74 (45-60° API)	0.80-0.74 (45-60°API)

[a]Data from Ontario Department of Mines and Northern Affairs (1970).

Abbreviations: API refers to the American Petroleum Institute scale of specific gravity; BCF = billion cubic feet of gas.

gas liquids along with the gas. On the other hand, dry gas reservoirs will produce largely methane and ethane with small percentages of heavier (propane and heavier) hydrocarbon gases. In a dry gas reservoir, hydrocarbon liquid is not condensed from the gas stream either in the reservoir or in flow lines (Amyx et al. 1960). Dry gases may contain water vapor which can condense during production.

1.039
Based on an analysis of gas-stream hydrocarbon components of Canadian offshore wells (Ont. Dep. Mines Northern Affairs 1970) and conversations with regional natural gas operators (Consumers' Gas 1979--personal communication; Runvik 1979--personal communication), it is believed that both Clinton-Medina and Lockport reservoirs developed in the Reference Program will behave for the most part as dry gas reservoirs; as these reservoirs are depleted and pressures decline during production, there is a possibility that some wells could behave as if they were located in wet gas reservoirs. This phenomenon would occur where liquids were present in the reservoir, trapped by permeability-porosity barriers, and drawn within the effective drainage radius of the wellbore by pressure decline with production. A small number of Reference Program wells will probably be drilled into isolated reservoir regions in direct contact with liquid hydrocarbons. Although this liquid will probably be incapable of flowing to the surface unless mechanically or physically aided, in the Reference Program any well that indicates a production potential of 5 gal/day* or more of natural gas liquids at the initial formation test would be plugged and abandoned (see Appendix A and Table 1-10). If the formation test indicates a production potential of less than 5 gal/day, the liquid zone could be cased off and production from other dry zones pursued.

Gas Stream Characteristics

1.040
Knowledge of the composition of target formation gas streams (Table 1-3) is essential for estimating the value of the gas as a fuel and for planning natural gas production facilities.

1.041
Although a few gas stream characteristics are routinely measured for processing and government reporting purposes, other characteristics important for environmental assessment purposes are either not measured or not available through government records. Much of the information used to develop lakewide average gas stream characteristics for Clinton-Medina sandstones and Lockport Formation was gathered through informal conversations with industry operators

*The 5 gal/day figure is used in the Reference Program as an indication of "significant liquid hydrocarbon production." This should not be interpreted as the recommended upper limit of allowable liquid hydrocarbon production. In the event that U.S. Lake Erie gas development were to be approved in principle, an actual limit could be established through appropriate mechanisms such as state leasing program requirements or standards set by state or federal water quality agencies. The Reference Program will be judged on its own assumptions and merits. Only careful data collection and record keeping can provide information necessary for an ultimate determination of limits on liquid hydrocarbon production.

Table 1-3. Gas Stream Characteristics (Lakewide Average for Reference Program)

Characteristic	Clinton-Medina Sandstones	Lockport Reefs
Methane as gas	87-93%	88-91%
Hydrogen sulfide as gas	0	1%; $\frac{\text{345 grain } H_2S}{\text{0.1 MCF natural gas}}$
Formation water produced as free liquid	$\frac{\text{3 bbl water}}{\text{MMCF natural gas}}$	$\frac{\text{3-5 bbl water}}{\text{MMCF natural gas}}$
Hydrocarbons produced as as free liquid	$\frac{\text{0.016 bbl condensate}}{\text{MMCF natural gas}}$	$\frac{\text{0.16 bbl condensate}}{\text{MMCF natural gas}}$
Thermal potential of gas upon combustion	$\frac{\text{1035 Btu}}{\text{CF natural gas}}$	$\frac{\text{1000-1025 Btu}}{\text{CF natural gas}}$

Abbreviations: bbl = barrel (42 gallons); MCF = thousand cubic feet of gas (under standard conditions unless otherwise noted); MMCF = million cubic feet of gas.

and utilities with regional field experience. Even when real data was available through government records, it represented site-specific conditions representative of only points within the Reference Program Study Region. After reviewing regional geologic literature, government records, and investigating operator experience in the field, the following estimates of gas stream characteristics were suggested as lakewide average values for use in the Reference Program.

1.042
The thermal potential of the gas as a fuel is excellent; average values for the Clinton-Medina and Lockport reefs exceed the value of 1000 Btu/ft^3 normally required for sales to natural gas distribution lines. The elevated thermal potential of Lake Erie gas also reflects an elevation in composition of the higher molecular weight fractions of gas (hexane and greater) over what might be expected in normal dry gas reservoirs. The isolated presence of hydrogen sulfide in Lockport reefs is a problem that will require separate production of Lockport reef and Clinton-Medina gas. Hydrogen sulfide is a toxic and corrosive gas (see Chapter Four - Air Quality, Impacts of the Reference Program); it must be maintained below toxic concentrations while drilling and must be removed from the gas stream at shore. The presence of H_2S at concentrations of 345 grains/0.1 MCF of natural gas would deteriorate onland distribution lines that have not been treated to tolerate the presence of H_2S prior to installation and would severely shorten their projected lifetime as well as pose an environmental and health risk during distribution onshore.*

*H_2S will be reduced to < 0.25 grains/0.1 MCF of gas at onshore treatment plants. All pipelines carrying gas that could contain H_2S will be constructed of materials that will resist corrosion from H_2S.

1.043
Estimates of the amount of formation water that would accompany the gas as free liquid to shore are only educated guesses based on conversations with operators in the region. The quantity of formation water that can be entrained as water droplets in the gas stream varies according to a number of factors such as pore space saturation, formation permeability, production pressures, and length of time the reservoir has been produced (reservoir age). Data reported from Canadian offshore Clinton-Medina production (Lawler Matusky & Skelly 1977) clearly shows a trend of increasing water production with increasing reservoir age (and presumably, pressure decline). Most field operators admit that both Clinton-Medina and Lockport reef wells can be damaged or ruined (production eliminated) through overproduction or premature vacuum-production with shore-based compressors. On average, 3 bbl of formation water will be produced per million cubic feet of Clinton-Medina or Lockport reef gas. When analyzing the effects of gasline breaks, wellhead breaks, or other accidents involving release of Lockport reef gas to the Lake, a worst-case value of 5 bbl/MMCF will be used. In any case, the anticipated formation water production from Lake Erie gas wells is significantly lower than values of 24.5 bbl/MMCF representative of marine offshore associated gas production (gas produced in association with oil) (Samsa et al. 1977).

1.044
The International Joint Commission has recommended that Lake Erie wet gas containing "appreciable amounts of liquid hydrocarbons" not be produced until the United States and Canada can agree on procedures for effectively responding to accidental liquid spills (Int. Joint Comm. 1970); although most gas wells drilled in the Reference Program Study Region could indicate production of only dry gas upon initial well tests, overall gas reservoir analysis suggests that small amounts of hydrocarbon liquids could be entrained in the gas stream along with formation water. Also, analyses of reservoir mechanics indicate that a small fraction of Reference Program dry gas wells could start to produce increasing amounts of hydrocarbon liquids as the wells age and reservoir pressures decline.

1.045
Records of liquid hydrocarbon production from gas wells are not kept in the region. In fact, most operators insist that properly managed Clinton-Medina and Lockport reef gas wells will not produce liquid hydrocarbons. But because records of produced formation water are also unavailable regionally, there is no way of knowing if liquid brines normally separated at the wellhead (onshore) or at a shore process facility (Canadian offshore gas development program) could be contaminated with small amounts of liquid hydrocarbons. In the absence of real data, a measure of total liquids recovered from a glycol reboiler stack used in a Canadian offshore Lake Erie gas dehydration unit was employed as a surrogate value for produced liquid hydrocarbons (Reeve-Newson 1979--personal communication). This value, 0.016 bbl of liquid hydrocarbon (condensate) per MMCF of gas produced, is important only as an order of magnitude indication useful for environmental assessment purposes, and was increased by an order of magnitude to generate a worst-case estimate of liquid hydrocarbons for accidents involving Lockport reef wells. It must be emphasized that in the Reference Program it will be assumed that even in properly managed Lake Erie gas reservoirs, production of no liquid hydrocarbons is impractical and, perhaps, impossible.

Natural Gas Production Information

1.046
The geologic strata underlying the Lake Erie watershed gently dip into the Appalachian Geologic Basin in a southeasterly direction. Despite variations in depths to target Clinton-Medina sandstones and thicknesses of their composite formations within and among states, average depths of 1800, 2500, and 2700 ft were assumed for New York, Pennsylvania, and Ohio. In Ohio, the Lockport reefs targeted for production (Table 1-4) vary in depth between 1800 and 2500 ft. A hydrostatic pressure gradient (0.433 psi per foot of depth) was assumed for all target reservoirs. Consequently, static bottom hole

Table 1-4. Natural Gas Production Information (Lakewide Average for Reference Program)

Parameter	Clinton-Medina Sandstones	Lockport Reefs
Depth to reservoir		
New York	1800 ft	-
Pennsylvania	2500 ft	-
Ohio	2700 ft	1800-2500 ft
Success ratio		
New York	85%	-
Pennsylvania	70%	-
Ohio	65%	90%
Productive life	20 years	15 years
Initial production rate at beginning of Year 1	300 MCF/day	950 MCF/day
Average daily production rate for Year 1	160 MCF/day	670 MCF/day
Static bottom hole pressure		
New York	780 psia	-
Pennsylvania	1080 psia	-
Ohio	1170 psia	780-1080 psia
Wellhead flowing pressure at beginning of Year 1	450 psia	800 psia

Abbreviations: MCF = thousand cubic feet; psia = pounds per square inch pressure (absolute reading).

pressures will range from 780 psia in New York to 1170 psia in Ohio. Anticipated success ratios (Table 1-4) are a function of both known production history in the region and assumptions concerning target formation characteristics, such as thickening of productive zones and increased numbers of zones, that can be correlated with production success. In the Reference Program, there will be an eastward trend of increasingly successful gas well drilling in Clinton-Medina sandstones. Since Lockport reefs are localized structural gas traps, once located and drilled, they will yield an even greater percentage of productive wells than stratigraphic Clinton-Medina reservoirs.

1.047
Average initial production rates and wellhead flowing pressures were estimated for both Clinton-Medina sandstones and Lockport reefs. Both gas production and flowing pressures were assumed to decline annually at the same rate. The shape of the decline curves (plotted as semilog functions, Figure 1-11) were constructed from investigations of the production history of onshore operators in New York and Ontario as well as documentable field production records (Redic 1970, 1974). Production information presented in Tables 1-5 and 1-6 was used to generate all natural gas production estimates from Clinton-Medina and Lockport reef wells in the Reference Program.

Factors That Constrain the Reference Program

1.048
Severe weather, winter ice cover, nearshore ice scour, lakebed conditions, potential geologic hazards, and special regional resource values influence the engineering design, timing, and siting components of the Reference Program. Constraints that have been incorporated into the Reference Program are presented in Table 1-7.

1.049
A broad range of weather conditions are experienced in the Lake Erie region--including high velocity winds, thunderstorms, hail, intense rain, snow, and glaze ice storms (Derecki 1976; U.S. Dep. Commer. 1978; Baldwin 1974; Tattleman and Gringorten 1973). New York and Pennsylvania preliminary offshore operational regulations (Appendix A) suggest drilling seasons to prohibit offshore activities when there is a significant chance of hazardous seasonal weather.* Suggested drilling seasons were adopted for use in the Reference Program. In the absence of state preliminary offshore operational regulations, Ohio was assigned an open drilling season identical to Pennsylvania's. The opening dates for drilling seasons conform with reported (Snider 1974) average navigation season beginning dates for Buffalo (April 10) and Cleveland (March 20).

1.050
Although from a strictly technological standpoint year-round extension of offshore drilling could be possible despite winter ice cover (Ireland 1979--personal communication), winter drilling is explicitly prohibited under

*New York has suggested an open drilling season between May 1 and October 31 (184 days), whereas Pennsylvania has suggested a longer season of April 1 through October 31 (214 days).

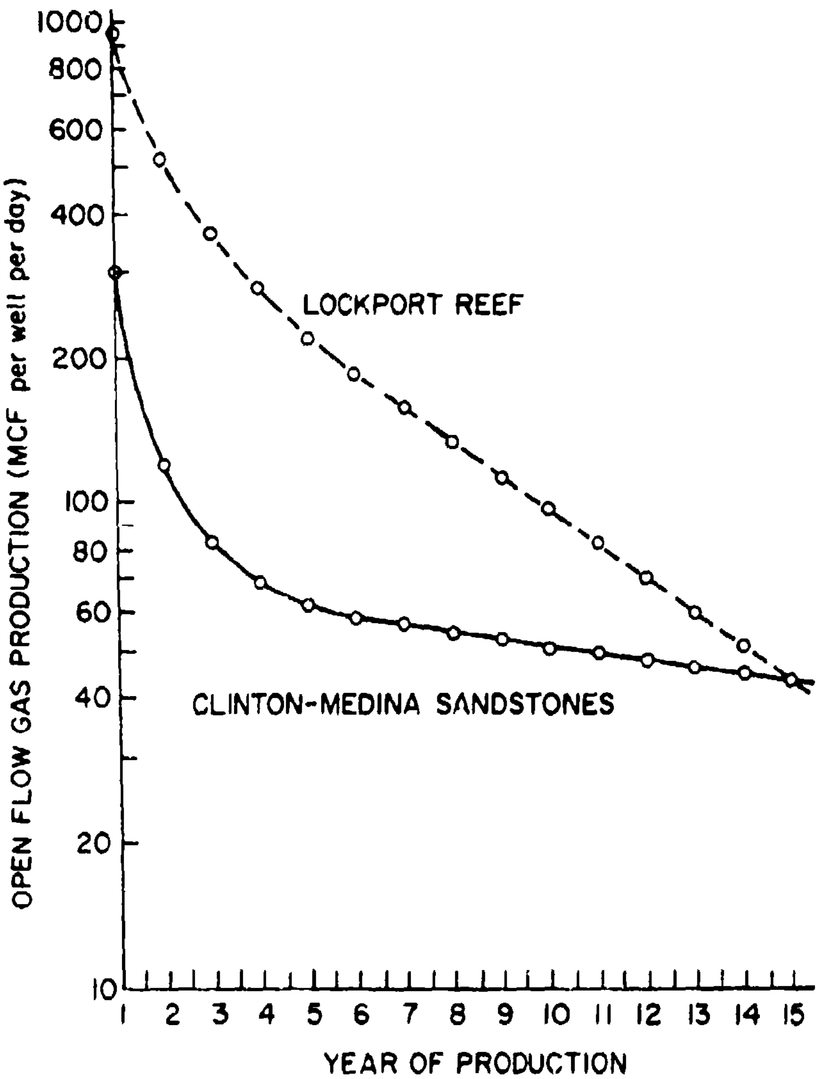

Figure 1-11. Reference Program Production Decline Curves for Clinton-Medina and Lockport Reef Wells.

Table 1-5. Estimated Production of Gas from Clinton-Medina Sandstones[a]

Year	Initial Prod. Rate at Beginning of Each Year (MCF/day)	% Decline from Preceding Year	Average Daily Production (MCF/day)	Average Annual Production[b] (360 days, MMCF/yr)	Average Annual Production[c] (288 days, MMCF/yr)
1	300	60	160	56	45
2	120	30	98	35	28
3	84	20	74	26	21
4	67	10	63	23	18
5	60	4	60	21	17
6	58	3	58	21	17
7	56	3	56	20	16
8	55	3	84	19	16
9	53	3	82	19	15
10	51	3	50	18	14
11	50	3	49	18	14
12	48	3	48	17	14
13	47	3	46	17	13
14	46	3	44	16	13
15	44	3	43	16	12
16	43	3	42	15	12
17	42	3	40	14	12
18	40	3	38	14	11
19	39	3	37	13	11
20	38	3	36	13	10

[a]The 360-day production year was established to demonstrate the effects of year-round production with glycol injection; the 288-day production year demonstrates the effects of decreased production resulting from hydrate formation without glycol injection.

[b]Estimated cumulative production over 20 years at 360 days/year = 410 MMCF.

[c]Estimated cumulative production over 20 years at 288 days/year = 330 MMCF.

Table 1-6. Estimated Production of Gas from Lockport Reefs[a]

Year	Initial Prod. Rate at Beginning of Each Year (MCF/day)	% Decline from Preceding Year	Average Daily Production (MCF/day)	Average Annual Production[b] (360 days, MMCF/yr)	Average Annual Production[c] (288 days, MMCF/yr)
1	950	45	670	240	190
2	520	30	420	150	122
3	370	25	300	110	88
4	270	20	240	86	69
5	220	15	200	72	58
6	190	15	170	62	50
7	160	15	150	53	42
8	130	15	120	45	36
9	110	15	100	38	30
10	97	15	90	32	26
11	83	15	76	27	22
12	70	15	65	23	19
13	60	15	55	20	16
14	51	15	47	17	14
15	43	15	39	14	11

[a]The 360-day production year was established to demonstrate the effects of year-round production with glycol injection; the 288-day production year demonstrates the effects of decreased production resulting from hydrate formation without glycol injection.

[b]Estimated cumulative production over 15 years at 360 days/year = 990 MMCF.

[c]Estimated cumulative production over 15 years at 288 days/year = 800 MMCF.

Table 1-7. Summary of Factors That Constrain the Reference Program

Constraining Factor	Limiting Characteristic of Constraining Factor	Reference Program Component Affected	Nature of Effect on Reference Program
Meteorology			
High velocity wind, glaze ice storms, and snow storms	Hazard to navigation and rig stability while in tow and onsite	Length of drilling season	Drilling season is closed on October 31.
Physical Limnology			
Waves	Hazard to rig stability while onsite	Rig design	Jack-up rigs are designed for maximum stability while exposing a minimum of surface area to wave energy (each rig has four legs and the capability to jack-up 12 ft out of water; see Table B.2). Floating rigs are designed to allow rotation around a central axis so that the rig can always face into the wind.
Ice cover	Obstruction to all Lake navigation	Length of drilling season	Opening dates for drilling season are designed to reflect average seasonal dates that ice clears from different sections of the Lake. Open drilling season: N.Y.: May 1 - October 31 (184 days) Pa.: April 1 - October 31 (214 days) Ohio: April 1 - October 31 (214 days)
Ice scour	Damage to underwater pipelines in shallow nearshore zones	Underwater pipeline design	Pipelines within the 30-ft water depth contour are buried to a depth of between 5 and 10 ft (actual depth based on site-specific conditions) to avoid damage from nearshore ice pileups.
	Damage to exposed wellheads in shallow nearshore zones	Wellhead siting design	Wellheads will be placed below the water/sediment interface in cellars (caissons) on the wells drilled by jack-up rigs in consolidated sediments.
Lakebed characteristics	Hazard to rig stability while onsite and while jacking out of muds	Selection of rig; rig siting criteria; jack-up rig design	Use of jack-up rigs is limited to lake areas with water depths less than 75 ft or mud depths less than 30 ft (areas restricted from jack-up rig use are shown in Figure 1-1 [map pocket]); jack-up rigs are designed with 20-ft^2 pads on each leg with high-pressure water jet systems for recovery from muds.
	Siting constraints for underwater pipeline routes	Underwater pipeline burial and securement procedures	Burial of pipelines at areas with exposed consolidated bedrock may be impractical; in areas outside the 30-ft water depth contour, pipes will be screw-anchored into consolidated sediments.
	Siting constraints for use of wellhead caissons	Wellhead siting design when using a floating rig	Although jack-up rig drilling program calls for a protective wellhead cellar below mudline, lacustrine muds and floating rig engineering limitations prohibit use of wellhead caissons in floating rig drilling programs.

Table 1-7. Continued

Constraining Factor	Limiting Characteristic of Constraining Factor	Reference Program Component Affected	Nature of Effect on Reference Program
<u>Potential Geologic Hazards</u>			
Upper Devonian shale gas	Unexpected kicks of high-pressure, small-volume gas can displace drilling fluids from wellbore and cause drilling hazards and potential environmental damage.	Safety equipment and casing program	Surface casing and riser pipe seal the wellbore from the Lake; blowout prevention (BOP) equipment and gas/liquid separators allow gases to be vented safely to the atmosphere.
Natural gas and saline water in Oriskany sandstones	If released to the Lake, natural gas and saline water could locally alter ambient Lake Erie water physical and chemical properties.	Drilling and casing program	Wells are drilled with fluids that can be adjusted for density, viscosity, salinity, pH, and other properties to control downhole hazards; drive pipe and surface casing is used wherever possible; gas/liquid separators allow any gases encountered to be vented safely to the atmosphere.
Upper Silurian salt beds	If released to the Lake, salts could dissolve and locally alter ambient Lake Erie water phyrical and chemical properties.	Drilling and casing program	Wells are drilled with fluids that can be adjusted for density, viscosity, salinity, pH, and other properties to control downhole hazards; to seal the wellbore from the Lake, drive pipe is set wherever possible and casing strings are used to total depth of the hole.
Lockport reef H_2S	If released to the Lake, H_2S in Lockport reef gas (345 grains/100 CF) would cause health and safety problems for exposed workers and could locally alter ambient Lake Erie water physical and chemical properties.	Casing and completion program; selection of pipes and wellheads; aboard safety equipment	Drive pipe and casing strings to total depth of the hole are used wherever possible to seal the wellbore from the Lake. Clinton-Medina and Lockport wells are completed and produced separately. Special "H_2S-treated" metals are used for Lockport reef wellheads and pipelines. Personnel are trained for H_2S hazards and safety equipment (oxygen packs, H_2S monitoring equipment) is deployed throughout the rig.
Liquid hydrocarbons in Ordovician and Cambrian formations	If liquid hydrocarbons were released to the Lake during well drilling, they could locally alter ambient Lake Erie water physical and chemical properties.	Drilling and casing program; safety equipment; waste management strategy	Wells are drilled with fluids that can be adjusted for density, viscosity, salinity, pH, and other properties to control downhole hazards; to seal the wellbore from the Lake, drive pipe is set wherever possible and casing strings are used to total depth of the hole. BOP equipment is available to stop pressurized flow of any liquids from the wellbore. Oil-contaminated drill cuttings and fluids are brought to shore and transported to treatment/disposal facilities. Once wells are completed and underwater pipelines are in place, materials should flow from reservoir to shore in a closed system. Leakage to the environment would result only from an accident.

Table 1-7. Continued

Constraining Factor	Limiting Characteristic of Constraining Factor	Reference Program Component Affected	Nature of Effect on Reference Program
Sensitive Areas			
Environmentally sensitive areas:			
Shore areas (sand dunes, wetlands, productive rivers and streams, erosion-prone bluffs)	Siting constraints for landfall locations	Landfall location and stabilization	Ten potential landfall zones (see Fig. 1-1, map pocket) have been located along the shore of Lake Erie; within each 10-mile zone, land/soil suitability-constraint analysis must be performed to select the optimal site; landfalls are sited in areas of artificial fill, low nonerodible bluffs, or low plains where possible and are not sited on or in sand dunes, wetlands, productive rivers and streams, or other environmentally sensitive areas.
			Landfalls and onland pipeline corridors are stabilized against erosion.
			Landfalls are located and constructed to minimize visual disruption of shoreline esthetics.
Dredge disposal sites	Drilling activities in disposal areas could resuspend sediments containing hazardous materials	Leasing strategy	Drilling is prohibited on designated dredge disposal areas (see Fig. 1-1, map pocket).
Presque Isle Preserve	Routine drilling activities are not compatible with the recreational and natural area values of Presque Isle	Leasing strategy	A buffer zone around Presque Isle suggested by the Commonwealth of Pennsylvania has been designated as an area prohibited from drilling activities (see Fig. 1-1, map pocket).
Nearshore buffer zone	Routine drilling activities should be displaced from the nearshore waters of the Lake which are intensely used by man for recreational and commercial fisheries, potable water supplies, and recreational water sports, and used by fishes for feeding and spawning	Leasing strategy	A buffer zone 1 mile from shore has been designated in which drilling is prohibited (see Fig. 1-1, map pocket).
Special administrative areas:			
Physical structure buffer zone	Rigs and vessels could collide with structures; accidental discharges could negatively affect water quality within close proximity of a potable water intake pipe.	Leasing strategy	Drilling is prohibited and pipeline corridors are excluded within 0.5 mile from a potable water intake and 1000 ft from any other physical structure.
State and international buffer zones	Drilling activities in one state or nation could interfere with natural gas reservoirs in close proximity across state or national boundaries.	Leasing strategy	Drilling is prohibited within a 0.5-mile strip of land adjacent (on each side) to state and national jurisdictional boundaries (see Fig. 1-1, map pocket).
Commercial sand and gravel areas	Drilling activities and pipelines would interfere with existing or potential commercial sand and gravel extraction operations where allowed.	Leasing strategy	Leasing of potential sand and gravel areas is postponed until sand and gravel is extracted.

Reference Program assumptions. Consideration of year-round drilling benefits and possible detriments to operators, states, and consumers is beyond the scope of this EIS.

1.051
Since jack-up rigs must be supported by the lakebed, they are constrained by engineering design (leg length) to a limited water depth and mud depth. Figure 1-1 (map pocket) depicts those areas of Lake Erie where water depths (greater than 75 ft) and/or mud depths (greater than 30 ft) would prohibit jack-up rig use (areas where combined water and mud depth exceed the length of leg needed to maintain the rig platform 12 ft above the lake surface). Mud depths greater than 30 ft also create problems when legs are extracted while jacking down.* The amount of offshore land that has been designated for access by jack-up rigs and floating rigs in the Reference Program is summarized in Table 1-8.

1.052
Geologic hazards include high-pressure, small-volume Devonian shale gas, Oriskany sandstone saline water, Silurian salt beds, and Lockport reef H_2S. These hazards can be avoided or mitigated through use of proper drilling, casing, and completion programs; blowout prevention equipment; and on-rig safety and monitoring equipment. The geologic hazards and corresponding precautions designed into the Reference Program are summarized in Table 1-7.

1.053
The Lake Erie region lies in the central stable region of the continent. Several seismically active areas have been identified in this region; one of these is in northwestern Ohio (near Anna), where a northeast-trending cluster of earthquake epicenters has been recorded. Figure 1-12 shows the limited extent of epicenters whose frequency of occurrence reaches 32 per 10,000 km^2. The trend of epicenters is nearly parallel to that exhibited by the Wabash River faults in southeast Illinois and suggests control by basement faults (Hadley and Devine 1974). A smaller cluster of epicenters exhibiting much less seismic frequency and earthquakes no greater than MM VI (Modified Mercalli scale of earthquake intensity) occurs in northeastern Ohio. No specific structural source has been identified, but obscure alignments suggest that movements on minor faults may be responsible (Hadley and Devine 1974).

1.054
A smaller seismic area in western New York and Ontario which trends westerly suggests control by an as yet unidentified structure; this structure seemingly parallels the strike of the Paleozoic rocks in the region. Earthquake intensity is low, except for an MM VIII earthquake that occurred near Attica, New York. This earthquake and smaller ones may be related to a very deep north-trending fault represented at the surface by the Clarendon-Linden structure. However, it is not clear what the relationship is between this north-south structure and the east-west seismic trend (Hadley and Devine 1974).

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*Although the Reference Program was designed to allow jack-up rig deployment in lake areas with mud depths up to 30 ft, Canadian offshore experience (Wooten 1979--personal communication) suggests that a decreased upper limit of 15 ft should be adopted in the event that U.S. offshore gas development is approved in principle.

Table 1-8. Summary of Offshore Land Areas Critical to Natural Gas Development in the Reference Program Study Region

Land Area	New York		Pennsylvania		Ohio		Total[a]	
	acres	mi^2	acres	mi^2	acres	mi^2	acres	mi^2
Total lake area in Reference Program Study Region	374,000	584	466,000	728	1,870,000	2,920	2,710,000	4,230
Sensitive areas[b] restricted from drilling	67,600	106	138,000	216	128,000	200	334,000	522
Nonproductive land area[c] in Clinton-Medina	-	-	-	-	428,000	669	428,000	669
Productive land area in Clinton-Medina	306,000	478	328,000	513	1,320,000	2,060	1,950,000	3,050
Productive Clinton-Medina land accessible by jack-up rigs	150,000	234	197,000	308	740,000	1,160	1,090,000	1,700
Productive Clinton-Medina land limited to floater rigs	157,000	245	131,000	205	578,000	903	866,000	1,350
Land area in identified Lockport reefs	-	-	-	-	244,000	381	244,000	381
Lockport reef land accessible by jack-up rigs	-	-	-	-	148,000	231	148,000	231
Lockport reef land limited to floater rigs	-	-	-	-	96,000	150	96,000	150

[a]Numbers may not add because of rounding.

[b]Special administrative areas and environmentally sensitive areas--including state and international buffer zones, the Presque Isle Preserve, and nearshore buffer zone (see Figure 1-1, map pocket).

[c]Clinton-Medina sandstones west of anticipated producing trend in offshore U.S. Lake Erie waters (see Figure 1-1, map pocket).

1.055
Earthquake hazards in the Lake Erie region range from low to moderately high. On a seismic risk map of the United States (Coffman and von Hake 1973), the western and central basins of Lake Erie are in Zone 1, portions of the eastern lake basin are in Zone 2, and the extreme eastern portion is in Zone 3. Zone 3 is an area of major expected damage corresponding to an earthquake of MM VII. A more recent study (Algermissen and Perkins 1976) indicates that although seismic events do occur in the Lake Erie region, they represent less risk than proposed in earlier evaluations (Lawler Matusky & Skelly 1977). Another study of seismic risk in the Dunkirk, New York, area concluded that the maximum earthquake that might occur would have an intensity of only MM V or VI (Lawler Matusky & Skelly 1977).

1.056
The overall frequency and intensity of seismic activity in the region is low and will probably not constrain Reference Program activities. In support of this conclusion, over 30 years of offshore drilling in Canadian waters of Lake Erie has not resulted in any documentable problems caused by seismic activity. According to Reference Program assumptions, earthquakes of intensity MM V or VI are expected to have little if any effect on offshore wells drilled and completed.

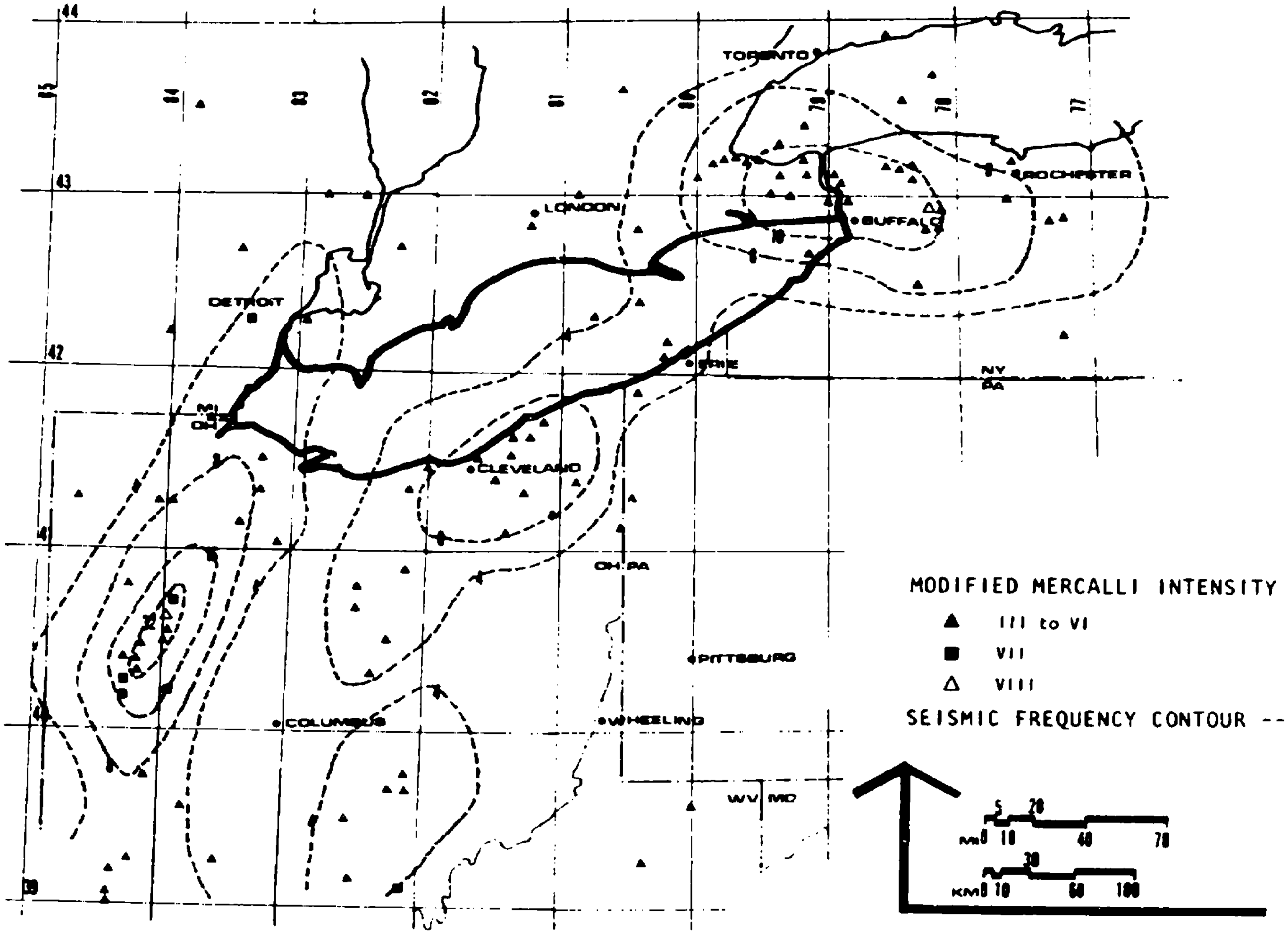

Figure 1-12. Map of Earthquake Epicenters in the Lake Erie Region. Locations of epicenters of earthquakes recorded during 1800-1972 are shown; only earthquakes with intensities equal to or greater than MM III are mapped. The "seismic frequency" contour (generalized) designates epicentral concentrations (number of epicenters per 10,000 km^2). Adapted from Hadley and Devine (1974).

1.057
Special regional resource values were identified and evaluated when designing the Reference Program. Environmentally sensitive areas and special administrative areas with varying constraining influence were defined; these areas and the nature of their influence on the Reference Program are summarized in Table 1-7. The amount of land that has been excluded from Reference Program leasing as a result of sensitive area classification is presented in Table 1-8.

1.058
At the 10 suggested Reference Program pipeline landfall zones (see Table 1-34), coastal zone shoreline types are characterized by varying degrees of erosional susceptibility. Study region shorelands are predominantly low to high bluffs (see Figure 1-13). Special siting considerations must be undertaken to locate candidate landfall sites where erosion is comparatively less problematic. Alternatively, special consideration must be given to engineering and design of pipeline construction and stabilization in areas where more favorable sites are unavailable or where the additional pipeline costs of alternative sites would be excessive.

1.059
Offshore sensitive areas including dredge disposal sites (U.S. Army Corps Eng. 1969; U.S. Dep. Commer. 1978), a buffer zone around Presque Isle, Pennsylvania (Pa. Dep. Health 1968), and a nearshore buffer zone (extending lakeward one mile from shore) were excluded from Reference Program leasing (Figure 1-1, map pocket); state leasing of special administrative areas, including buffer zones around physical structures and jurisdictional boundaries, was also prohibited (see Table 1-7). Existing sand and gravel resource areas (Ohio Dep. Nat. Resour. 1959; Buschman 1979) and potential future sand and gravel sites (Lewis 1967) are mapped on Figure 1-1 (map pocket); Reference Program leasing strategy was designed to postpone drilling activities in these areas until the sand and gravel industry exhausted its interests. Once in place, wellheads and underwater gas gathering pipelines would preclude future sand and gravel dredging over developed natural gas fields.

Administrative Policy Assumptions

Introduction

1.060
At this time, no federal or state agency has formally approved a plan for natural gas development in Lake Erie. Consequently, no detailed policy for federal and state government interaction is available to guide the creation and implementation of a Reference Program. An administrative framework for the Reference Program is available from an interpretation of current environmental and natural gas laws and regulations created to protect the environment and regulate gas development on land. Various assumptions have been made to complete and adapt these existing laws, rules, and regulations for use in an offshore program (see Table 1-9).

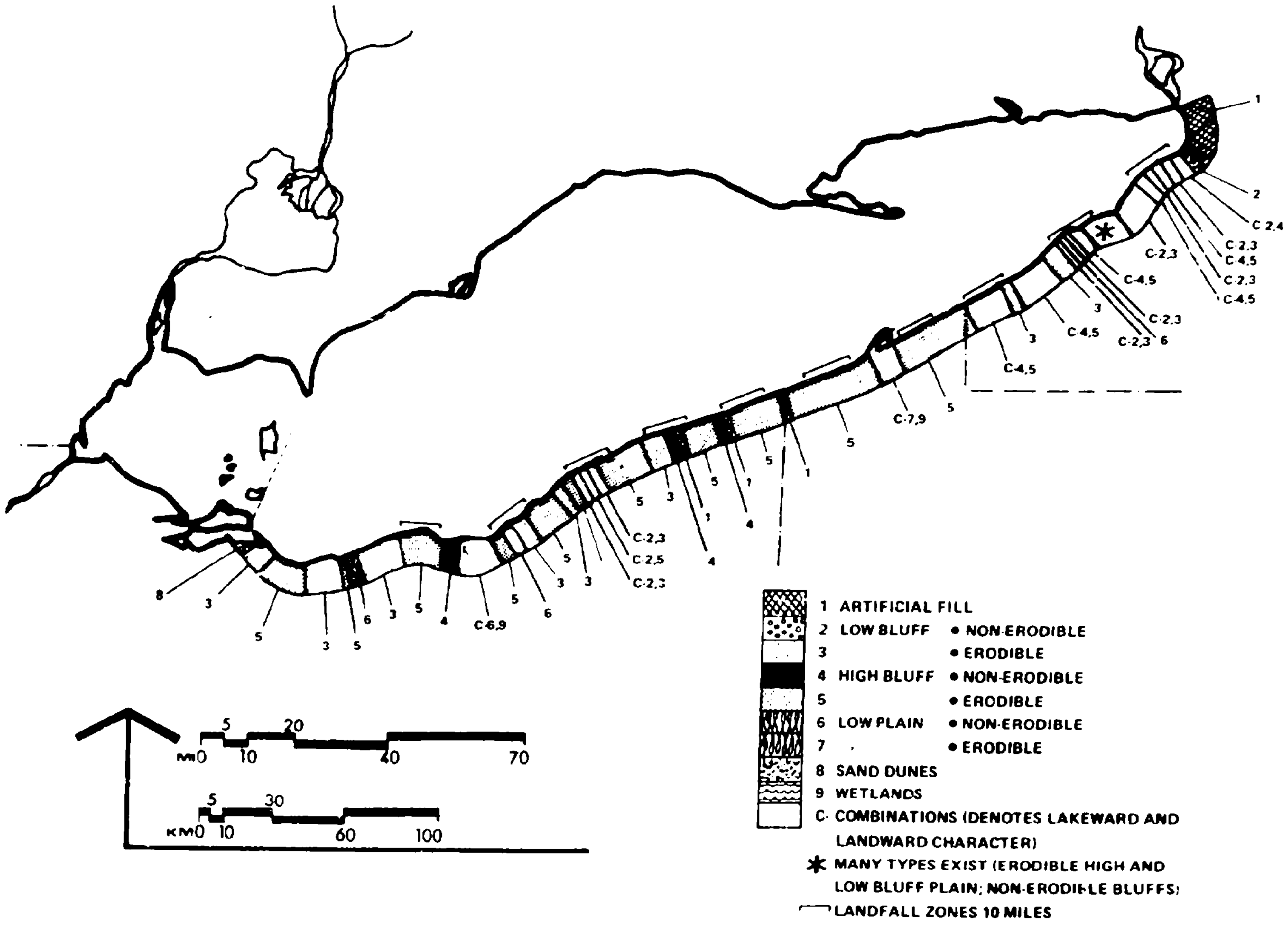

Figure 1-13. Coastal Zone Shoreline Types in the Reference Program Study Region.

Table 1-9. Existing Administrative Laws and Regulations Used to Establish Reference Program Administrative Policy

Existing Conditions	Reference Program Assumptions
All lands under Lake Erie in the Reference Program Study Region and their mineral rights are the property of New York, Pennsylvania, or Ohio, and these states have the exclusive right to grant mineral leases. None of these states currently has a ban on offshore drilling. New York and Pennsylvania have approved legislation encouraging offshore development; Ohio does not yet have such legislation.	New York, Pennsylvania and Ohio will allow development of offshore natural gas resources in Lake Erie
Administration of New York state lands submerged beneath Lake Erie is a responsibility of the Office of General Services; environmental and gas activities are regulated by the Department of Environmental Conservation. New York's Department of Transportation has authority for the state's oil spill contingency plan. Pipeline siting authority is vested in the New York Public Service Commission.	All environmental and gas-related activities will be coordinated by one designated state agency (offshore program office)[a]
In Pennsylvania, the Geological Survey of the Department of Environmental Resources has responsibility for establishing and enforcing a regulatory program for offshore operations; the Bureau of Forests has responsibility for administrating a leasing program.	All environmental and gas-related activities will be coordinated by one designated state agency (offshore program office)[a]
Ohio's Department of Natural Resources regulates the state's leasing and gas production activities; environmental matters are the responsibility of the Ohio Environmental Protection Agency. Pipeline siting authority is vested in the Ohio Power Siting Commission.	All environmental and gas related activities will be coordinated by one designated state agency (offshore program office)[a]
Each state has unique environmental laws and regulations.	A uniform set of environmental regulations for offshore gas development will be implemented by each state.
No state has a final statutory or regulatory program for offshore operations in Lake Erie, although they all have existing oil and gas programs for land operations.	Each state will develop and implement a program designed specifically for production of natural gas from under its waters. Each state will use a common, baseline set of operating standards in its program.
The U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, Coast Guard, and Department of Transportation have regulatory authority for various aspects of any offshore development.	The state agency will be the lead agency in coordinating the state and federal agencies' regulatory actions over offshore gas development

[a]The state offshore program office is suggested as an administrative tool to expedite interactions between the lessee and federal and state regulatory agencies, e.g., ensuring that applicants are aware of all necessary permits, assisting them in filing applications, and reviewing the status of applications. Coordination of federal and state regulatory actions does not mean that the office will exercise regulatory authority not clearly granted to it or explicitly reserved by agency-enabling legislation, implementation regulations, etc.

1.061
New York, Ohio, and Pennsylvania own the mineral resources under their waters of the Lake.* Primary responsibility for both implementing a leasing program and defining and enforcing a set of rules and regulations that govern offshore activites has been entrusted to each state. The states, through their legislatures, have delegated their power to lease the land to appropriate state agencies.

Administrative Program Assumptions

1.062
Each state has laws and regulations that control onland leasing programs, oil and gas development, water quality, air quality, waste disposal, and other environmental matters. New York and Ohio have at least two state agencies that could be given administrative responsibilities under these existing mandates (see Table 1-9). Also, various state agencies have responsibility for pipeline siting and oil spill contingency plans. The Reference Program has been designed with the assumption that leasing and regulatory functions will be coordianted by a single responsible state agency. Consequently, although the existing onland gas program requires a developer to obtain leases and permits from a number of state agencies, under the Reference Program a developer will deal with a "one-stop" state agency** to obtain the necessary permits.†

1.063
The first step in implementing this program would be the creation of a regulatory Task Force representing the three states and appropriate federal agencies. The Task Force would develop the following: standard lease forms, drilling permit forms, and construction and operation permit forms. The Task Force would be responsible for recommending a set of minimum federal standards to guide offshore Lake Erie natural gas development activities. It could draw upon the expertise of the existing Interagency Study Group, which is currently serving to support the entire environmental assessment process (this Interagency Study Group has already reviewed the issues analysis report, "An Examination of Issues Related to U.S. Lake Erie Natural Gas Development" [September 1978], that preceded development of this EIS). Comments made in response to review of this programmatic EIS by both the Interagency Study

*State title to the beds of navigable internal waters comes from the English Crown for the original thirteen states [Mumford v. Wardwell, 73 U.S. 423, 435 (1867), and from the "equal footing doctrine" for the remaining states [Pollard's Lessee v. Hagan, 44 U.S. 212 (1845)].

**Although a "one-stop" offshore gas agency may or may not be legally feasible in a state, the intention of proposing such an agency is to centralize most, if not all, responsibilities for the program so that an environmentally safe and economically feasible program can occur.

†New York has passed the Uniform Procedures Act (Article 70, Environmental Conservation Law, Chapter 723 of the Laws of 1977) which deals with the administration of programs for state environmental regulation. While it is a step in providing a comprehensive environmental review system, the Act does not provide for a "one-stop" system.

Group and the general public will be helpful in developing a more refined set of program guidelines where appropriate. The Task Force and its responsibilities will not preempt existing federal permit application review requirements.

1.064
The Task Force would also recommend the necessary enabling legislation to authorize offshore gas drilling and would create a standing review committee representing the three states and appropriate federal agencies to monitor administrative progress, maintain uniformity of the regulatory program, and communicate with state authorities about the program. This enabling legislation is anticipated to be the only legislative action required to implement the uniform program. Legislative approval of the enabling legislation would be required in each state. An integral part of the legislation would be the designation of one office (the one-stop state agency/offshore program office) in each state to manage the total program. The complexity and extensiveness of the proposed offshore program requires that one body reviews all aspects of a state's program so that a well-planned and environmentally acceptable program can occur.

1.065
Each state will develop its own requirements for competitive bidding, rental fees, royalty fees, insurance bonds, and other financial matters. It is anticipated that each state will offer a unique set of lease requirements to potential industry operators. Independent and distinct lease requirements could foster healthy competition among the three states.

Regulatory Program Assumptions

1.066
Variations among state environmental and engineering regulations could provide disincentives for operators to lease from a state with justifiably rigorous standards for protection of lake resources. Although each state has the right to define its own set of rules and regulations governing offshore activities (e.g., drilling and casing procedures, drilling fluid programs, procedures for collecting and storing materials used and residuals generated, waste disposal requirements, use of safety equipment, installation of wellheads and pipelines), a single set of minimum operating standards* is assumed to be adopted by each state (see Table 1-10). Adoption by states of minimum uniform operating standards acceptable to federal agencies may also be assumed to facilitate state and federal coordination during permit review processes and to reduce duplication of effort.

1.067
Where independent state environmental programs have made possible the existence of multiple standards of environmental acceptability, the most rigorous ones have been chosen and identified as the standard of acceptability against which consequences of gas development activities can be compared (Table 1-10) It is unlikely that the permitting and regulatory authority for water quality, air quality, and waste disposal would be consolidated into a single office for

*The activities governed by these rules and regulations are being measured in the context of this EIS against a test of environmental acceptability.

Table 1-10. Summary of Existing and Proposed Environmental Standards Used to Define a Reference Program for Lake Erie Natural Gas Development

Requirements	Regulatory Authority	Status
WATER QUALITY		
No discharge of drilling fluids	40 CFR 435	Existing[a] (federal)
Drill cuttings may be discharged, but shall contain no free oil	40 CFR 435	Existing (federal)
Drill cuttings will be collected aboard rigs, stored, and brought to shore for disposal[b]	State regulations and lease stipulations	Assumed (state)
Wells with the potential for producing greater than 5 gal/day of liquid hydrocarbons upon initial formation test would be plugged and abandoned; in wells with a potential less than 5 gal/day, the liquid zone could be cased off and production from other dry zones pursued[c]	State regulations and lease stipulations	Assumed (state)
Deck drainage can be discharged after treatment	40 CFR 435	Existing (federal)
Deck drainage will be collected aboard rigs and brought to shore for treatment and disposal[b]	State regulations and lease stipulations	Assumed[a] (state)
No discharge of stimulation fluids	40 CFR 435	Existing[a] (federal)
No discharge of produced waters	40 CFR 435	Existing (federal)
No discharge of sanitary and domestic wastes	40 CFR 435; Ohio Revised Code, Chap. 1547; N.Y. Navig. Law, Sec. 33-c	Existing (federal and state)
State water quality standards for Lake Erie: Dissolved Oxygen — 6 mg/L Total Dissolved Solids — 200 mg/L Coliform — 200/100 mL Oil and grease — No floating oil pH — 6.5-9.0 Phenols — 0.001 mg/L Toxics — 1/100 of 96-hour TLm of LC_{50}	State regulations (generalized from Ohio Admin. Code, Rule 3745-1-10)	Assumed[d,e] (state)
Spill Prevention Control and Countermeasure Plan (SPCC)	40 CFR 112; 40 CFR 1510; State plans	Existing (federal and state)
NPDES Permit	40 CFR 122-125; 6 N.Y. Codes, Rules & Regs. § 7.50-57; Ohio Admin. Code, § 3745-33-01 to 3745-33-10	Existing[f] (federal and state)
AIR QUALITY		
Diesel engines must meet New Source Performance Standards	40 CFR 60	Assumed (federal)
Vented or flared gases are subject to Prevent Significant Deterioration (PSD) permit	40 CFR 52.21	Existing (federal)
Fugitive hydrocarbon emissions are subject to PSD permit	40 CFR 52.21	Existing (federal)

Table 1-10. Continued

Requirements	Regulatory Authority	Status
AIR QUALITY (continued)		
H_2S must not exceed ambient ground-level concentration of 0.1 ppm/h	25 Pa. Code § 121 et seq.	Assumed[g] (state)
Onshore facilities will be subject to PSD and Offset Policy	40 CFR 52.21 (PSD); 40 CFR 51 (Emissions offset)	Existing (federal)
WASTE DISPOSAL		
Produced waters may be reinjected into suitable onshore host formations or disposed of onshore in approved surface pits	Safe Drinking Water Act, Sec. 1421 (44 FR 23738, April 20, 1970); Resource Conservation and Recovery Act Subtitles C and D (43 FR 58946, Dec. 18, 1978, and 43 FR 4366, Feb. 1, 1978)	Assumed[f,h] (federal)
Drilling fluids shall be treated and disposed of in approved Resource Conservation and Recovery Act (RCRA) landfills	RCRA Subtitle C (43 FR 58946, Dec. 18, 1978)	Assumed[a] (federal)
Sanitary and domestic wastes shall be delivered to approved onshore pump-out facilities	N.Y. Navig. Law 833-C; 30 Pa. Cons. Stat. Ann. § 200 Chap. 1547	Existing (state)
Deck drainage must be treated and disposed of in approved onshore sites	RCRA Subtitle C (43 FR 58946, Dec. 18, 1978)	Assumed (federal)
LOCATION/SITING		
Setting of drilling rigs shall meet Corps of Engineers, Section 10, and state obstruction to navigation-type permit requirements and avoid reserved areas	River and Harbor Act Sec. 10; N.Y. Codes, Rules & Regs. § 608; 32 Pa. Cons. Stat. Ann. § 681 et seq.	Existing[i] (federal and state)
Offshore gas and glycol lines must meet Corps of Engineers Section 10 and Section 404 permit requirements and state pipeline construction requirements. The pipelines and associated trenching in Lake Erie would require authorization under Section 10 of the River and Harbor Act of 1899. Precast pipes do not constitute the discharge of a pollutant through a point source and are not regulated under Section 404 of the Clean Water Act. However, dredged or fill material used as backfill or bedding for pipeline crossings is considered an activity covered under Section 404 of the Clean Water Act. This fill requires an individual permit under Section 404 unless criteria of 33 CFR 323.4-3 (a) (1) and (b) are met for nationwide authorization. Another activity associated with the drilling program that is subject to Section 404 regulation is the discharge of or pouring of concrete irrespective of the use of containing cells and forms.	River and Harbor Act Sec. 10; Clean Water Act of 1977, Section 404[f], state) N.Y. Codes, Rules & Regs. § 608	Existing[j,k] (federal and
Onshore facilities, including distribution/transmission lines, must meet above requirements plus obtain siting permit	Ohio Revised Code, Chap. 4906; N.Y. Pub. Serv. Law, Article VII	Assumed[l] (state)
All activities must be compatible with approved state coastal zone management (CZM) programs; operators will be required to submit a certificate of compliancy to the Corps, pursuant to Section 307 of the Coastal Zone Management Act	State CZM plans approved pursuant to federal Coastal Zone Management Act, Sections 306 and 307 [15 CFR 923 (43 FR 8378, Mar. 1, 1978)]	Assumed[m] (state)

Table 1-10. Continued

Requirements	Regulatory Authority	Status
MISCELLANEOUS		
Pipelines must be buried to a depth of between 5 and 10 ft within the 30-ft water depth contour offshore[c]	State regulations and lease stipulations	Assumed (state)
Water-bearing strata must be sealed off[c]	State regulations and lease stipulations	Assumed (state)
Pipelines, landfalls and other facilities must be constructed to withstand ice and wind damage from 100-year storm[c]	State regulations and lease stipulations	Assumed (state)
Dry holes and abandoned wells must be plugged[c] according to program described in Tables 1-22 and 1-23	State regulations and lease stipulations	Assumed (state)

[a]Assumes hazardous constituents.

[b]An environmental standard has been adopted for Reference Program use that is different and more restrictive than the existing standard.

[c]No standard currently exists.

[d]Generalized from state of Ohio.

[e]Ohio has brought suit against USEPA (44 FR 39487, July 6, 1979) for its rejection of revisions to Ohio water quality standards adopted by the state (Ohio ex rel. Mc Aroy v. EPA, No C-2-79-827).

[f]Assumes the establishment of a consolidated permit program of NPDES, RCRA Hazardous Waste, Safe Drinking Water, Underground Injection Program, and Section 404 Permit Program in Phase II and III waters.

[g]Generalized from state of Pennsylvania onshore ambient standards and state of Texas operating requirements.

[h]Assumed that proposed federal underground injection program (Safe Drinking Water Act) regulations will govern reinjection, and RCRA Subtitle C and Subtitle D proposed requirements will govern onshore disposal practices.

[i]Generalized from New York's and Pennsylvania's requirements.

[j]The consolidated permit regulations (40 CFR Parts 122, 123, and 124, June 14, 1979), as proposed by the USEPA, and the NPDES revisions of June 7, 1979, would allow states to administer Section 404 permits in Phase II and III waters. However, Phase I waters, such as Lake Erie and other navigable waters including their adjacent wetlands, are not subject to delegation.

[k]Generalized from New York's requirements.

[l]Generalized from New York's and Ohio's power siting requirements.

[m]All three states assumed to have approved Coastal Zone Management plans.

Abbreviations: CFR = Code of Federal Regulations; FR = Federal Register.

offshore gas development. In the Reference Program, it is assumed that although various permitting authorities would remain in various state offices, all requests, evaluations, and reviews would go through the offshore program office and this office would work jointly with the appropriate state office in administrating the permit program. For instance, an operator would apply to the offshore program office for an NPDES permit; the office would ensure that applicants are aware of all necessary permits, assist in filing applications, review the status of applications, etc.; the appropriate state or federal agency would grant the permit. All review and monitoring of permit restrictions would remain the responsibility of the permitting agency.

1.068

Financial support for these activities will originate from operator payments to the states as stipulated in the lease provisions for competitive bidding, annual rental, and royalties. These revenues will come either directly to the state agency responsible for enforcement or to the state treasury for distribution to the agency through annual appropriations as determined by the state legislatures.

1.069
Although the individual states will have primary authority over development of gas under the Lake, the federal government also has the authority and responsibility to regulate certain aspect of gas development activities. Although certain permitting and enforcement responsibilities mandated by the Clean Water and Clean Air Acts have been transferred to the states, the USEPA is required to develop effluent guidelines for the oil and gas industry and standards for air and water quality for the lake area. It also has the authority to review, veto, and enforce state-issued NPDES permits. Also, USEPA is currently designing regulations implementing the Resource Conservation and Recovery Act and the Safe Drinking Water Act, which may affect the disposal of wastes generated from the program (see Tables 1-11 and 1-12). The USEPA's Office of Federal Activities will also review and comment on Section 10 and Section 404 permit applications. Thus, USEPA has a limited regulatory role over gas development activities, but the agency's actions will affect engineering and environmental control practices of the operators and describe its own responsibilities and those of the state agencies.

1.070
The regulatory involvement of the Corps in Lake Erie gas development is related to its authority to issue or deny permits under Section 10 of the River and Harbor Act of 1899 (33 U.S.C. 403) and Section 404 of the Clean Water Act (33 U.S.C. 1344a). Under Section 404 of the Clean Water Act, the Corps has jurisdiction over the discharge of dredged spoil or fill material that may occur in the Lake and other waters of the United States including their adjacent wetlands. A permit will have to be obtained by the operator for any activity (e.g., backfill over pipelines, discharge of concrete, pipeline bedding, fill associated with landfall construction), that is considered by the Corps to result in the discharge of dredged or fill material into the Lake or along the shoreline below the ordinary high water mark or in other waters of the United States (see Table 1-13). Depending on site-specific factors and/or extent and design of construction and construction methodology, the authorization could be in the form of an individual permit, nationwide permit, or general permit. A permit must also be obtained from the Corps in accordance with Section 10 of the River and Harbor Act. Section 10 permits would be required for any work or structures in or affecting navigable waters of the United States (see Table 1-14). In the case of gas development in Lake Erie, work such as dredging, drilling, and placement of structures such as anchored drill rigs, pipelines, wellheads, and docking facilities in navigable waters would require Section 10 authorization. Lake Erie, various harbors along Lake Erie, and portions of certain Lake Erie tributaries are considered navigable waters.

1.071
The regulatory permit review performed by the Corps is conducted in conjunction with the states. Before a permit can be granted for an activity that may result in the discharge of a pollutant into waters of the United States, a State Water Quality Certification (Section 401 of the Clean Water Act) is required. If water quality certification is not granted or waived by the state, the Corps would not issue the permit. In addition to Water Quality Certification, Corps permit applications are also subject to review and comment by the states. If a state permit is required for the same activity covered by Corps permits and if that state permit is denied, the Corps would

Table 1-11. Waste Disposal Facility Requirements Under Proposed Resource Conservation and Recovery Act Regulations[a]

Nonhazardous	Hazardous[b]
Disposal facility may not be located in a wetland unless: An NPDES Permit has been obtained. A Corps of Engineers Section 404 Permit has been obtained where construction of a levee or other containment structure is involved. Disposal facility may not be located in critical habitat areas without approval of the Office of Endangered Species, Fish and Wildlife Service, Department of the Interior. Disposal facility may not be located in recharge zone of a sole-source aquifer unless: Other disposal methods have been determined technologically or economically infeasible. Designed, operated, maintained, and monitored to prevent contamination of the aquifer. State waste disposal facility standards must be met.	Owners/operators of disposal facility must obtain detailed chemical and physical analyses of wastes identifying hazardous characteristics. Disposal facilities may not be located in active fault zones, regulatory floodways,[c] coastal high hazard areas,[c] a 500-year floodplain, wetlands, or in the recharge zone of a sole-source aquifer. Protection of endangered species must be assured. Active portions of the facility must be 200 ft from the property line. Security measures must include a 6-ft fence around active portions of the facility, controlled access, and posting of warning signs. Manifest, recordkeeping, and reporting requirements must include: Establishing a manifest system for acknowledging receipt of hazardous waste shipments; manifests are to be kept on record for at least 3 years. Maintaining a log of all hazardous wastes treated, stored, or disposed of to include description of wastes, quantities, and methods used and dates of treatment, storage or disposal. Notifying U.S. Coast Guard National Response Center or regional onsite coordinator of any discharge of hazardous waste, fire, or explosion at the facility. Maintaining a groundwater and leachate monitoring program and reporting monitoring data to USEPA regional administrator. Notifying EPA regional administrator prior to cessation of facility operation. Submitting an annual report to the USEPA regional administrator which summarizes the facility's operation [Annual report requirements are detailed in 43 Fed. Regist. 58946, Dec. 18, 1978, Section 250.43-5(c) (5) (i-iii)]. Submitting a quarterly report on all deliveries of hazardous wastes which were not accompanied by a manifest. Owners/operators of disposal facilities must conduct and record daily inspections of the facility's operation and equipment. Removal of hazardous wastes is not required as part of closure operations in the case of the special wastes subcategory. Owners/operators and a registered professional engineer must certify that closure has been conducted so as to protect human health and the environment after closure. A post-closure monitoring and maintenance program must be enforced by the owners/operators for a period of 20 years after closure.

[a] 43 Fed. Regist. 58946, December 18, 1978.

[b] If determined hazardous in accordance with Secion 250.13 of the proposed RCRA Regulations (43 Fed. Regist. 58946, December 18, 1978), the criteria listed for the "special wastes" subcategory of hazardous wastes will apply to production brines and drilling muds.

[c] As defined by the Federal Insurance Administration.

Table 1-12. Permit Requirements for Underground Injection Wells Under Safe Drinking Water Act Regulations: Class II, Enhanced Recovery, Hydrocarbon Storage, and Produced Fluids (Nonhazardous)[a]

Construction

Casing and cementing requirements to be based on: depth of injection zone; injection pressure; hole size; size and grade of casing strings; corrosiveness of native fluids; lithology of injection and confining intervals.

Logs and testing to include: sure-shot surveys; resistivity, spontaneous potential, caliper, porosity, and gamma ray logs before casing is installed; cement bond and fracture finder logs after casing is set and cemented.

Information concerning the injection formation must include at a minimum: fluid pressure; temperature; fracture pressure; other physical and chemical characteristics of the injection matrix; physical and chemical characteristics of formation fluids; and compatibility of injected fluids with formation fluids.

Operation

Injection pressure may not exceed a maximum which would cause fractures or allow migration of fluids into an underground drinking water source.

Injection between the outermost casing and the wellbore is prohibited.

Monitoring and Reporting

Monitoring of injection pressure, flow rate, and cumulative volume not less than weekly for brine disposal, monthly for enhanced recovery operations, and daily during injection or withdrawal of stored hydrocarbons.

Monitoring of equipment at least once every 5 years to demonstrate mechanical integrity.

Maintenance of monitoring records for 3 years.

Monitoring of nature of injected fluids often enough to yield data on characteristics of injected fluids.

Abandonment of Wells

Before abandonment, well must be in a state of static equilibrium, with mud weight equalized top to bottom.

Performance bond required.

Additional Information

Map showing location of injection well(s) and applicable area of review (not less than 1/4 mile radius); location of all producing wells, injection wells, abandoned wells, dry holes, and water wells of public record within the area of review.

For all wells in the area of review which penetrate the proposed injection zone, each well's type, location, depth, and record of plugging and/or completion.

Average and daily maximum injection pressure, injection rate, and volume of injection fluids.

Source and characteristics of injection fluids.

Engineering drawings of surface and subsurface construction plans.

Descriptions of formation testing program, monitoring program, stimulation program, and injection procedures.

Accident or failure contingency plans.

Appropriate geological data on injection zone and confining strata.

Geologic name, lateral extent, and depth of all underground sources of drinking water which may be affected by injection.

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[a]40 CFR 146 (44 Fed. Regist. 23738, April 20, 1979).

Table 1-13. Application Requirements for Federal Section 404 Permits, Discharge of Dredged Spoil or Fill Material into Waters of the United States[a]

Application Contents
Complete description of the proposed activity including:
Construction plans and drawings
Location, purpose, and intended use of proposed project
Proposed scheduling
Identification of adjacent property owners
Location and dimensions of adjacent structures
Other approvals required by federal, interstate, state, and local authorities
Description of the type, composition, and quantity of material to be dredged.
Description of dredging methods and plans for disposal site.
Where disposal will be into U.S. waters, identification of:
Source of material
Type, composition, and quantity
Method of transport and disposal
Location of disposal site
Additional information as required by the District Engineer, including environmental data.

[a]Source: Section 404, Regulatory Program of the Corps of Engineers, 33 CFR 320, 323, 325 (42 Fed. Regist. 37144, July 19, 1977). Permit applications are coordinated with federal, state, and local agencies, and the views of the general public are solicited.

administratively deny the federal permit.* Even when there is no state permit requirement, the official views of the state on a Corps permit application are given considerable weight. New York has an existing permit program that regulates the same types of activities under Corps jurisdiction (Table 1-14). States with approved Coastal Zone Management (CZM) plans must also concur with an applicant's certification that the activity will comply with coastal zone plans. No federal permit would be issued without this concurrence. In addition to state involvement with Corps permit reviews, the views of other federal, state, and local agencies and the general public (individuals, groups, organizations, local officials, legislators, businesses, etc.) would be solicited during the processing of applications. Thus, through its permitting authority, the Corps of Engineers has jurisdiction over certain aspects of gas development under the Lake.

1.072
Another federal agency that would become involved with offshore gas development is the U.S. Coast Guard through its navigational responsibilities. The Coast Guard is empowered to: protect navigable waters from environmental harm

*Where the required federal, state, and/or local certification and/or authorization has been denied, the application for a Department of the Army permit will be denied without prejudice to the right of the applicant to reinstate processing if subsequent approval is received [33 CFR 320 (j) (1)].

Table 1-14. "Obstruction to Navigation" Permit Requirements

Federal Section 10 Permit Requirements[a]

Permit Applicability

All structures and works in or affecting navigable water of the U.S. (including Lake Erie) except bridges and causeways.

Fixed or floating aids to navigation.

Artificial islands and fixed structures on the OCS.

Power transmission lines.

Permit Requirements

Applications received by District Engineer.

Coordination with Coast Guard required.

Approval may be by letter of permission, individual permits, or general permits.

Coordination with federal, state, and local agencies, and solicitation of views from the general public are required.

Review Criteria

Public interest; wetlands protection; fish and wildlife; water quality; historic, scenic, and recreational values; interference with adjacent properties or water resource projects; and consistency with state coastal zone management plans (state certification required).

State Obstruction to Navigation-Type Permit Requirements[b]

Permit Applicability

Activities resulting in the disturbance of streambeds or banks.

Excavation or fill operations in navigable waters.

Construction of docks, wharves, piers, or landing facilities.

Permit Requirements

Proposed activity will not endanger public health, safety, or welfare.

There will be no unreasonable, uncontrolled, or unnecessary damage to natural resources (soils, forests, wildlife, etc.).

Disturbance of streambeds or banks will not cause: increased erosion; loss of cropland or forests from flooding; loss of water for beneficial use; increased turbidity; deposition of silt and debris; and irregular variations in water velocity, temperature, or level.

[a]Source: Section 10, Regulatory Program of the Corps of Engineers, 33 CFR 322 (42 Fed. Regist. 37139, July 19, 1977).

[b]Source: New York Rules on Use and Protection of Waters, Part 608, Chapter V, Resource Management Services, Official Compilation of Codes, Rules, and Regulations, May 1, 1972.

resulting from damages to or destruction of vessels and structures; develop safety requirements for rigs and support vessels, as well as passengers and crew; control the handling and transportation of inflammables, corrosives, compressed gases, poisons, and hazardous substances; and respond to pollution incidents in the Lake. An operator would be required to meet the Coast Guard's regulations for rigs and support vessels and notify the agency of an incident.

1.073
The Department of Transportation is responsible for the safety of pipeline facilities and the transportation of gas. Since the Reference Program assumes that the lake gas will be a commodity marketed through interstate commerce, all pipelines must meet the department's regulations for design, construction, installation, operation, replacement, maintenance, and inspection. Although no federal pipeline permit is currently required, the Reference Program is designed so that operators in each state will be required to obtain a pipeline construction permit similar to that required in New York (Table 1-15).

Table 1-15. Assumed Permit Requirements for Pipeline Construction

Construction of pipelines in excess of 125 pounds per square inch pressure and over 1000 ft long requires issuance of a "Certificate of Environmental Compatibility and Public Need" by the regulatory authority.

An "Environmental Maintenance Construction Plan" (EMCP) must be submitted by the applicant; contents of plan must include:

- Description of and impacts on land uses, cultural resources, water quality, and wetlands within the proposed pipeline corridor and a 5-mile area on either side of the corridor.
- Identification of area affected on U.S. Geological Survey topographic maps.
- Construction plan showing where and how pipeline will be constructed, how rights-of-way will be maintained and restored, and what safety measures will be used.

60-day period after submittal of EMCP is provided for evaluation by Public Service Commission (including onsite investigations, public interviews, and consultation with appropriate state agencies).

1.074
As discussed, three federal agencies have been identified that would have authority over certain aspects of the development of Lake Erie gas. These three agencies would be involved at various times and in different manners due to their responsibilities and the evolving nature of the Reference Program. To provide a systematic and simplified procedure for fulfilling agency mandates, it has been assumed that these three agencies will work closely with the appropriate "one-stop" state agency within the structure of the Task Force. The operator will meet concurrently with representatives from the state agency and the three federal agencies after the granting of the lease; at least once a year the operator will describe his program and timetables, apply for all necessary permits, and arrange for inspections, monitoring, surveillance, and other necessary procedures. The state agency will be the lead agency in coordinating the activities of the four agencies to allow the operator to develop his gas leases. All the agencies will have designed an appropriate scheme allowing for yearly permits to avoid the problem of frequent permit review. The operator, in turn, must provide the necessary information and notify the agency of any changes not described in the operator's permits. This coordinated approach by the state and federal agencies has been assumed because of the overlap of interests and authorities and the need for each agency to assess the total development program to carry out its responsibilities.

1.075
In conclusion, there will be one administrative agency (offshore program office) in each state with responsibility for coordinating all aspects of that state's offshore development program. All appropriate federal agencies that have authority over part of the program will work with and through this state agency. Although a one-stop state agency can coordinate certain aspects of federal regulatory programs--such as ensuring that applicants are aware of all necessary permits, assisting them in filing applications, reviewing the status of applications, and informing them of federal requirements--it cannot, under present laws and regulations, carry out federal NEPA responsibilities. Assuming that the Reference Program were approved in principle, upon receipt of a permit application from an operator, the Corps would have to decide whether an EIS or an extended environmental assessment were required; the need for

additional site-specific data for permit processing would also be addressed. NEPA determinations would be made on a case-by-case basis for each permit application.

Accident Contingency Plans

1.076
A mechanism for interactive government response to Reference Program accidents is mandated through the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 1510); this plan (hereafter referred to as the National Plan) provides for establishment of regional and state plans and offers guidelines for these plans. Proposed regulations revising the National Plan (44 Fed. Regist. 28196, May 14, 1979) have been published but have not become final at this time. Although final revisions in the National Plan will eventually be incorporated in regional and state plans, this discussion is limited to a description of contingency plans as they currently function. The following contingency programs are applicable to the Reference Program: Great Lakes Region Oil and Hazardous Substances Contingency Plan, Joint Canada-United States Marine Pollution Contingency Plan, state contingency plans, and Spill Prevention and Control Contingency Plans.

1.077
The Great Lakes Region Oil and Hazardous Substances Contingency Plan (GLCP) was adopted in 1975 as part of the National Plan. The purpose of the GLCP is to provide an effective and coordinated approach to reporting, evaluating, and responding to pollution incidents in order to maximize efforts for containment and removal of oil and hazardous substances.

1.078
A National Response Team, composed of various federal agencies, becomes active in responding to emergencies that cannot be contained by the appropriate regional authority or that constitute a threat to many people or a significant amount of property. A Regional Response Team, comprised of representatives from the regional federal offices, has similar advisory and administrative functions as the National Response Team and is also responsible for coordinating and determining the extent of the National Response Team. The Regional Response Center is headquartered at the Office of the Commander, Ninth Coast Guard District, Cleveland, Ohio.

1.079
Initial and onsite responsibility for control of polluting discharges is placed with the onsite coordinator. Two onsite coordinators have been designated under the GLCP: the Captain of the Port, Buffalo, New York, and the Captain of the Port, Cleveland, Ohio. The onsite coordinator is required to: (1) ascertain the characteristics, size, and location of the discharge, (2) determine the impacts to human health, natural resources, and the environment, (3) prioritize corrective action based on these impacts, (4) initiate various resources as deemed necessary, and (5) inform the National Response Team of response progress.

1.080
A list of about 50 contractors is maintained by the Coast Guard to conduct cleanup and removal operations. Selection of the contractor is generally

based on expertise in handling special types of discharge incidents. A Coast Guard National Strike Force may be mobilized by the onsite coordinator in extreme emergencies.

1.081
Funds are available for reimbursing state and local governments for the cost of discharge control and removal through a Pollution Revolving Fund, administered under the GLCP by the Comptroller, Ninth Coast Guard District. Owners/operators are liable to the U.S. Government for costs of cleanup and removal, except where it is demonstrated that the discharge was caused solely by an act of God, an act of war, negligence by the U.S. Government, or negligence by a third party.

1.082
In the event of pollution discharge incidents affecting or potentially affecting both U.S. and Canadian waters, the Joint Canada-United States Marine Pollution Contingency Plan (JCP) becomes operational. Response and administrative activities established by the JCP are essentially the same as those in the GLCP. A Joint Response Team, consisting of representatives of agencies in the United States and Canada, functions basically on the same level as the Regional Response Team under the GLCP. Joint Response Centers are headquartered in the Ninth Coast Guard District Office, Cleveland, Ohio, and in the Ministry of Transport, Marine Services Office, Toronto, Canada. Onsite commanders are designated in the JCP and have the same duties and responsibilities as assigned under the GLCP to onsite coordinators.

1.083
New York, Pennsylvania, and Ohio have Oil and Hazardous Substances Contingency Programs that operate separately from the Great Lakes Regional Plan and are applicable to discharges occurring onshore. Actual cleanup activities are coordinated with the U.S. Coast Guard except in cases of very minor discharge incidents. None of the three states has entered into agreements with the U.S. Coast Guard under the GLCP to participate in the Pollution Revolving Fund. In all three states, recovery of costs and determination of liability follow federal procedures specified in Section 311 of the Federal Water Pollution Control Act.

1.084
Section 311(j)(1)(C) of the Clean Water Act (Pub. L. 95-217) authorizes the President to issue regulations establishing procedures, methods, equipment, and other requirements to prevent discharges of oil and hazardous substances from vessels and onshore and offshore facilities and for containment of such discharges. Regulations have been promulgated by the USEPA to prevent oil spills from nontransportation-related facilities (40 CFR 112) and are referred to as the spill prevention control and countermeasure plan (SPCC). Regulations have been proposed (40 CFR 151; 43 Fed. Regist. 39276, Sept. 1, 1978) to prevent discharges of hazardous substances; the approach is similar to the one developed and used in the EPA's SPCC plan for oil pollution prevention. It is assumed that these regulations will apply to the gas development program. An SPCC plan for oil and hazardous substances must be developed by owners/operators of offshore facilities and approved by the appropriate agency as part of the NPDES permitting process. The proposed standards would be the minimum required to implement best management practices for prevention of discharges of toxic and/or hazardous substances. All SPCC plans must be certified by a registered professional engineer.

Leasing Strategy

1.085
Throughout the environmental impact statement, a number of terms will be used when discussing gas development activities and analysis of costs and environmental impacts. Many of the terms and their definitions are taken from New York's and Pennsylvania's proposed lease requirements and offshore rules and regulations (see Appendix A). The conditions presented in the definitions of terminology (Table 1-16) will serve as a basis for the Reference Program economic analysis.

1.086
In the Reference Program, it is assumed that New York, Pennsylvania, and Ohio initiate lease sales simultaneously in 1980. Each state solicits nominations of prospective lease areas from interested industry operators. From all nominations received, the leasing agencies determine which lease areas will be included in each state's first lease sale. These areas are presented to prospective operators for competitive bonus bids. Development rights for each lease area are granted to the highest bidder who is judged professionally qualified to develop gas resources in a manner specified by the state.

1.087
Two distinct target formations have been identified for U.S. waters of Lake Erie: Clinton-Medina sandstones and Lockport reefs. Production from the Lockport Formation in Pennsylvania and New York will be commingled with Clinton-Medina production. High anticipated concentrations of H_2S in Ohio Lockport reefs will require separate production from Lockport and Clinton-Medina gas wells. Since Lockport reef production--as indicated by anticipated initial flow, flowing wellhead pressures, and production decline--is superior to Clinton-Medina production, there will be competition among operators to lease and produce these reefs as quickly as possible. Leasing interest in Clinton-Medina formations will be highest in offshore tracts located along producing trends extropolated from known onshore U.S. reservoirs (see Figure 1-1, map pocket).

1.088
Reference Program lease areas were delineated to identify the amount of land that could be drilled by one operator in a 10-year period (primary lease term). The operator would be forced to rebid on land not dedicated to wells after 10 years. Strict operational rules and regulations imposed by the states (summarized in Appendix D) and relatively large capital requirements compared to onshore development of similar gas resources would limit the number of potential operators willing to mobilize risk capital in the study region. For the purpose of the Reference Program, it is assumed that three operators would ultimately obtain lease rights to the Reference Program Study Region.* Each operator would have the prerogative to dedicate as many drilling rigs to each lease area as desired. The number of rigs deployed would be

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*This assumption should not be interpreted as a limitation of lease rights to three operators if gas development is found to be acceptable; nor does it mean that three specific operators have expressed an interest in gas development to the Corps or the USEPA.

Table 1-16. Reference Program Lease Terminology

Operator	The firm that acquires the natural gas development rights to any lease area; it is assumed that the operator will provide the risk capital needed to procure the drilling rig(s) required.
Tract	The area contained within 1 minute latitude and 1 minute longitude (approximately one square mile) that serves as the smallest leasable unit of land.
Block	The area contained within 5 minutes latitude and 5 minutes longitude (approximately 25 square miles); Lake Erie has been divided into numbered blocks in anticipation of a tract and block leasing program.
Lease area	An area of land (measured in tracts and blocks) assumed to be leased by an industry operator; Lake Erie has been divided into 16 lease areas which serve as the basic units of analyses for the Reference Program (see Figure 1, map pocket).
Field	The amount of land within any lease area that contains all the wells that could be drilled in one year; it is assumed that all wells in a newly drilled field begin producing at the start of the following year.
Cash bonus bid	A sum of money that represents a prospective operator's degree of financial interest in acquiring lease area development rights; the bid is offered to the state and must compete against any other interested operator bid in a public auction; it is assumed that each state will require a bid that is equal to or exceeds the minimum annual rental fee required.
Primary term	A period of time (not to exceed 10 years) allowed to an operator to establish natural gas production in a lease area.
Secondary term	The period of time following initial production from a gas well or a maximum of 5 years during which production from individual tracts fails to generate annual royalty payments equal to delay rental fees.
Delay rental	An annual fee charged to operators for use of state owned lease areas during the primary lease term; the cash bonus bid replaces delay rental for the first year of the primary term; rental fees are reduced by the proportion of acreage attributed to producing tracts in the lease area. <u>Delay Rental Schedule</u> New York: $2.00/acre/year Pennsylvania: $1.00/acre/year Ohio: $2.00/acre/year
Shut-in rental	An annual fee charged to operators (equivalent to delay rental fees) for acreage attributed to completed wells that are not generating royalty fees equal to delay rental fees.
Royalty payment	A fee paid by operators to the state based on a percentage of the existing market value of the produced gas or, at the discretion of the state, the same percentage quantity of gas produced. <u>Royalty Payment Schedule</u> New York: 16.7% Pennsylvania: 12.5% Ohio: 16.7%

allocated to drill in U.S. lease areas over the lifetime of the program. The rig allocation scheme is presented in Table 1-17.

1.089
The physical shape of Reference Program lease areas was developed from a number of environmental and engineering constraints as well as assumptions concerning relative operator interest in specific land areas based on anticipated gas production and operational costs. Dredge disposal sites, the Presque Isle Reserve, and state, international, nearshore, and physical structure buffer zones were all eliminated from land dedicated to lease sales. Lakebed areas that could potentially yield commercial sand and gravel were grouped together into individual lease areas. Lease sales in these areas were postponed until late in the program to allow sand and gravel extraction without conflict with gas development activities. Lockport Reefs were organized into lease areas drillable in 10-year periods. Clinton-Medina sandstones directly offshore from known U.S. onshore reservoirs were divided into individual lease areas. Lacustrine mud depths and water depths served as boundaries for lease areas serviced by jack-up and floater rigs. The lease areas are identified in Figure 1-1 (map pocket).

Table 1-17. Allocation of Jack-up and Floater Rigs Throughout the Reference Program

		Lease Areas																
		New York			Pa.		Ohio											Total Rigs Per Year
Interval	Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	
1	1980		Ja[a]			Jb								FB	Jc			4
2	1981		Ja			Jb								FB	Jc			4
3	1982		Ja			Jb								FB	Jc			4
4	1983		Ja		FC	Jb						Je		FB	Jc,d			7
5	1984		Ja		FC	Jb						Je		FB	Jc,d			7
6	1985	Ja		FA[b]	FC	Jb						Je		FB	Jc,d			8
7	1986	Ja		FA	FC	Jb						Je		FB	Jc,d			8
8	1987	Ja		FA	FC	Jb						Je		FB	Jc,d			8
9	1988	Ja		FA	FC	Jb						Je		FB	Jc,d			8
10	1989			FA	FC	Jb	Ja					Je		FB	Jc,d			8
11	1990			FA	FC	Jb	Ja					Je		FB	Jc,d			8
12	1991			FA	FC	Jb	Ja			Jc,d		Je		FB				8
13	1992			FA			Ja	FC	FB	Jc,d	Jb,e							8
14	1993			FA			Ja	FC	FB	Jc,d	Jb,e							8
15	1994			FA			Ja	FC	FB	Jc,d	Jb,e							8
16	1995			FA			Ja	FC	FB	Jc,d	Jb,e							8
17	1996						Ja	FC	FB				FA					4
18	1997						Ja	FC	FB				FA					4
19	1998						Ja	FC	FB				FA					4
20	1999						Ja	FC	FB				FA					4
21	2000						Ja	FC	FB				FA					4
22	2001							FC	FB				FA					3
23	2002							FC	FB				FA					3
24	2003							FC	FB				FA					3
25	2004								FB				FA					2
26	2005												FA					1
27	2006												FA			Jc,d		3
28	2007															Jc,d	FB	3
29	2008															Jc,d	FB	3
30	2009																FB	1
31	2010																FB	1
32	2011																FB	1
33	2012																FB	1
34	2013																FB	1

[a] J = Jack-up rig (separate lower-case letter a through e for each rig).

[b] F = Floater rig (separate upper-case letter A through C for each rig).

1.090
Time requirements to drill individual wells, drilling success ratios, and drilling season lengths were used to determine the number of total wells, productive wells, and dry holes drilled annually in each lease area. Drilling programs defined to minimize environmental, health, and safety risks (see Tables 1-22 and 1-23); rig requirements; and depth to formations were factors considered in estimating the time requirements for individual wells. The time required to drill each lease area was determined from well spacing, wells drilled per year, and drillable land per lease area. All of the factors are summarized in Table 1-18 for Clinton-Medina lease areas and Table 1-19 for Lockport reef lease areas. A tally of total, productive, and nonproductive wells drilled in each state is presented in Table 1-20.

Description of the Reference Program

Introduction

1.091
Based on realistic assumptions concerning physical properties of gas-bearing target formations, factors constraining offshore development activities, administrative organization, and leasing strategy, a Reference Program was defined for environmental analysis. This Reference Program will be presented in three sections: routine activities, construction activities, and anticipated hazards and accidents with potential environmental consequences. In each case, the nature and timing of events will be outlined. Materials used and residuals generated will be identified and the fate of these materials and residuals will be described. Generally, materials and residuals can either be released to the environment (geologic formations under the Lake or onshore, Lake water, atmosphere, or land), recovered and reused, or stored and disposed of onshore. Where disposal of materials and residuals is indicated, a waste management strategy is suggested; in all cases this strategy is based on contemporary interpretation of appropriate environmental laws and regulations. Activities discussed in all three sections are organized by four phases corresponding to the sequence of events that normally take place in hydrocarbon development programs: exploration, development, production, and decommissioning (Table 1-21). The information presented in this section was used to identify impacts that are assessed in Chapter 4 of the EIS.

Routine Activities

Nature and Timing of Events

1.092
Before any operator would be willing to commit large amounts of capital to rigs, hardware, and shore facilities, the location and extent of gas-bearing formations must be determined. Due to the economic advantages of producing gas from Lockport reefs in comparison to Clinton-Medina sandstones, the first year of the Reference Program will be dedicated largely to identifying the location of any reefs within lease areas. Seismic analysis of lakebed stratigraphy is one means of doing this. The analysis is accomplished by means of a survey conducted by one vessel (see Appendix B, Table B.1) equipped to emit innocuous levels of sound energy into the Lake. Reflected energy is received by the same vessel and later processed to highlight faults, salt beds, subsurface structures, and general stratigraphy. A seismic survey of the

Table 1-18. Summary of Geologic, Engineering, and Administrative Assumptions Defining a Reference Program Leasing Strategy for Clinton-Medina Wells

	Lease Areas															
	New York			Pennsylvania		Ohio										
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
Length of drilling season (days)	184	184	184	214	214	214	214	214	214	214	214	214	214	214	214	[illegible]
Objective formation	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	LR	LR	CM	CM
Depth to formation (feet)	1800	1800	1800	2500	2500	2700	2700	2700	2700	2700	2700	2700	a/	a/	2700	2700
Drillable land (mi^2)	98	136	245	204	308	290	258	286	259	208	231	237	150	231	119	150
Rig requirement	J	J	F	F	J	J	F	F	J	J	J	F	F	J	J	F
Well spacing (acres)	640	640	640	640	640	640	640	640	640	640	640	640	320	320	640	640
Success ratio	85	85	85	70	70	65	65	65	65	65	65	65	90	90	65	65
Time required to drill producing well (days)	6.5	6.5	7.8	9.3	8.3	8.8	9.8	9.8	8.8	8.8	8.8	9.8	a/	a/	8.8	9.8
Time required to drill dry hole (days)	5.3	5.3	7.8	9.3	7.1	7.6	9.8	9.8	7.6	7.6	7.6	9.8	a/	a/	7.5	9.9
Total wells drilled per year	29	29	24	23	27	26	22	22	26	26	26	22	a/	a/	26	22
Producing wells drilled per year	25	25	20	16	19	17	14	14	17	17	17	14	a/	a/	17	14
Dry holes drilled per year	4	4	4	7	8	9	8	8	9	9	9	8	a/	a/	9	8
Time required to drill lease area (years)[b]	3.4	4.7	10.2	8.9	11.4	11.1	11.7	13.0	5.0[c]	4.0[c]	8.9	10.8	11.5	10.6[d]	4.6	6.8
Total wells drilled in lease area	98	136	245	204	308	290	258	286	259	208	231	237	299	462	119	150
Producing wells drilled in lease area	85	117	204	142	217	190	164	182	169	136	151	151	268	409	78	95
Dry holes drilled in lease area	13	19	41	62	91	100	94	104	90	72	80	86	31	53	41	55

[a] See summary sheet for Lockport reefs, Table 1-19.

[b] Assumes one rig per lease area unless indicated otherwise.

[c] Calculated on the basis of two rigs per lease area starting in the first year of drilling; see Table 1-17.

[d] Calculated on the basis of 1 rig per lease area for three years after which it is joined by another rig for the remainder of the drilling period (see Table 1-17).

[e] Lease Area XV is actually Lease Area XIV redrilled for deeper Clinton-Medina gas at 640 acres per well spacing; land in Lease Area XIV west of the Clinton-Medina producing trend boundary (Figure 1-1, map pocket) is deleted when calculating producing land in XV.

[f] Lease Area XVI is actually Lease Area XIII redrilled for deeper Clinton-Medina gas at 640 acres per well spacing.

Table 1-19. Summary of Geologic, Engineering, and Administrative Assumptions Defining a Reference Program Leasing Strategy for Ohio Lockport Reef Wells[a]

	Lease Areas								
	XIV		XIII						
	L_1	L_2	L_2	L_3	L_4	L_5	L_6	L_7	L[illegible]
Depth to formation (feet)	2500	2300	2300	2300	1800	1800	2300	2300	2300
Drillable land (mi^2)	225.0	6.0	24.0	4.0	10.0	95.0	9.0	4.5	3.0
Rig requirement	J	J	F	F	F	F	F	F	F
Well spacing (acres)	320	320	320	320	320	320	320	320	320
Success ratio	90	90	90	90	90	90	90	90	90
Time required to drill producing well (days)	8.3	7.8	9.0	9.0	7.8	7.8	9.0	9.0	9.0
Time required to drill dry hole (days)	6.5	6.0	9.0	9.0	7.8	7.8	9.0	9.0	9.0
Total wells drilled per year	26	28	24	24	27	27	24	24	24
Producing wells drilled per year	23	25	22	22	24	24	22	22	22
Dry holes drilled per year	3	3	2	2	3	3	2	[illegible]	2
Time required to drill lease area (years)[a]	17.30	0.43	2.00	0.33	0.74	7.04	0.[illegible]	[illegible].33	0.25

[a]Assumes one rig per reef.

Table 1-20. Numbers of Wells Drilled by Jack-up and Floater Rigs in New York, Pennsylvania, and Ohio Reference Program Target Formations

Formation; Rig	New York	Pennsylvania	Ohio	Total
Clinton-Medina; Jack-up				
Total wells	234	308	1107	1649
Productive wells	202	217	724	1143
Dry holes	32	91	383	506
Clinton-Medina; Floaters				
Total wells	245	204	931	1380
Productive wells	204	142	592	938
Dry holes	41	62	339	442
Total Clinton-Medina				
Total wells	479	512	2038	3029
Productive wells	406	359	1316	2081
Dry holes	73	153	722	948
Lockport Reef; Jack-up				
Total wells	--	--	462	462
Productive wells	--	--	409	409
Dry holes	--	--	53	53
Lockport Reef; Floater				
Total wells	--	--	299	299
Productive wells	--	--	268	268
Dry holes	--	--	31	31
Total Lockport Reef				
Total wells	--	--	761	761
Productive wells	--	--	677	677
Dry holes	--	--	84	84
Total Lake				
Total wells	479	512	2799	3790
Productive wells	406	359	1993	2758
Dry holes	73	153	806	1032

Table 1-21. Sequence of Events in Lake Erie Reference Program

1. EXPLORATION
    - 1.1. Seismic Survey
    - 1.2. Basement Test Wells
2. DEVELOPMENT
    - 2.1. Site Preparation
        - 2.1.1. Survey lakebed topography and stability
    - 2.2. Move Onsite and Rig Up
        - 2.2.1. Tow rig to site
        - 2.2.2. Set rig on location (legs or anchors)
        - 2.2.3. Set caisson (jack-up only)
        - 2.2.4. Set 16-inch drive pipe (jack-up only)
    - 2.3. Drill Surface Hole
        - 2.3.1. Drill 20 ft into competent bedrock
            - 2.3.1.1. Set and cement casing
    - 2.4. Drill Secondary Surface Hole to Bottom of Middle Devonian (Drillship Only)
        - 2.4.1. Set and cement casing
    - 2.5. Drill Production Hole
    - 2.6. Perform Drill Stem Test
        - 2.6.1. Collect and separate gas/liquid returns
        - 2.6.2. Determine if well should be stimulated and produced, or plugged and abandoned
    - 2.7. Plug and Abandon Dry Holes
    - 2.8. Complete Potential Producer Well
        - 2.8.1. Set and cement production casing
        - 2.8.2. Run production tubing into hole
        - 2.8.3. Circulate hole with completion fluid
        - 2.8.4. Spot perforation zone with acid and additives
        - 2.8.5. Remove blowout prevent equipment and riser pipe
        - 2.8.6. Install wellhead and connect annulus line and tubing line to rig deck
        - 2.8.7. Swab well down to 450 ft below mud line
        - 2.8.8. Perforate well, remove annulus line and tubing line
        - 2.8.9. Attach flowline to wellhead
        - 2.8.10. Move rig offsite
    - 2.9. Stimulate Potential Producer Well from Stimulation Barge
        - 2.9.1. Move barge onsite, connect pressure lines
        - 2.9.2. Inject fracturing materials
        - 2.9.3. Collect and separate gas/liquid returns, store liquids aboard
        - 2.9.4. Disconnect return flowline, flow well on camel for 12 hours, move barge offsite
        - 2.9.5. Attach flowline to wellhead
        - 2.9.6. Determine if well should be produced
3. PRODUCTION
    - 3.1. Flow Gas to Shore
        - 3.1.1. Measure gas production at shore facilities
        - 3.1.2. Maintain wellheads and pipelines with divers
    - 3.2. Process Gas at Onshore Facilities
        - 3.2.1. Remove free water from gas stream
        - 3.2.2. Compress gas to meet transmission line standards
        - 3.2.3. Remove H_2S from gas stream (Lockport gas only)
            - 3.2.3.1. Run gas through methyl ethyl amine (MEA) unit to strip H_2S from gas stream
            - 3.2.3.2. Convert H_2S to elemental sulfur with Claus recovery unit
            - 3.2.3.3. Run tailgas through Shell-Claus Offgas Treater to reduce SO_2 emissions
        - 3.2.4. Run gas stream through triethylene glycol (TEG) unit to dry gas (remove water vapor) and recover glycol injected into the gas stream at the wellhead
        - 3.2.5. Reinject glycol into flowlines leading to wellhead from shore facility
4. DECOMMISSIONING
    - 4.1. Plug and Abandon Depleted Wells
        - 4.1.1. Remove wellheads and tubing
        - 4.1.2. Set plugs in wellbore
    - 4.2. Remove Pipelines to Abandoned Wells

Reference Program Study Region has already been performed (Petty-Ray Geophysical Operations, Houston, Texas). Potential operators could either purchase data collected from this survey or contract for collection of new data.

1.093
Once Lockport reefs are identified through interpretation of processed seismic data, comprehensive stratigraphic and reservoir data would be collected by drilling exploratory wells at locations where reefs are expected. Neither exploratory nor developmental wells would be drilled in any area identified as environmentally sensitive or as a special administrative area (see Table 1-7). Exploratory wells will be drilled on-structure through the reef(s) and into Cambrian basement rocks. At least four basement test wells will be drilled in the first year of the Reference Program. Since every well drilled could indicate the presence of producible quantities of natural gas, the same drilling procedures will be used for both exploratory and developmental wells. Enough exploratory wells will be drilled to confirm the nature of regional stratigraphy, reservoir characteristics, and the location of target formations. At this point, developmental drilling is initiated; most wells will only be drilled to Lower Silurian depths (from 1800 to 2700 ft). An overview of activities critical to both exploratory and developmental well drilling are generalized and discussed below under developmental drilling.

1.094
During developmental drilling, a jack-up or floating rig (Figure 1-14) is towed to a well site by a tug. The jack-up rig is a movable platform capable of being elevated and supported above the water on legs (see Appendix B, Table B.2). Although both floating barges and drillships could be used in areas where water or mud depths prohibited the siting of a jack-up rig, a floating drillship (see Appendix B, Table B.3) was chosen for analysis in the Reference Program because of its increased stability under expected meteorological conditions. Once the rig is on location, a well is drilled and completed according to the programs listed in Tables 1-22 (see also Figure 1-15) and 1-23. In addition to rigorous standards for drilling safety and environmental protection (e.g., total-depth casing, weighted drilling fluids, BOP equipment), drip pans, interior and exterior pipe wipers, mud pit monitors, and kick detectors will be used on all rigs.

1.095
All materials used and residuals generated that are designated for shore disposal are containerized aboard a barge stationed alongside the rig. The barge is towed to shore by a tug when necessary. At the dock, drill cuttings, spent drilling fluids, sewage, and other wastes are offloaded and transported by truck to designated waste-treatment/disposal facilities (see section on Waste Management Strategy). Materials such as food, fuel, drilling fluid components, and pipe are brought daily to the rig by a service vessel (see Appendix B, Table B.4). Personnel may be ferried to and from the rig by either the service vessel or helicopter.

1.096
After drilling and completing a well in approximately 5 to 10 days, the drilling rig is jacked down and its legs are jetted out of the sediments; the rig is then moved to a new well site by a tug (for discussion of potential environmental impacts resulting from moving offsite, see Chapter Four - Water Quality and Aquatic Ecology).

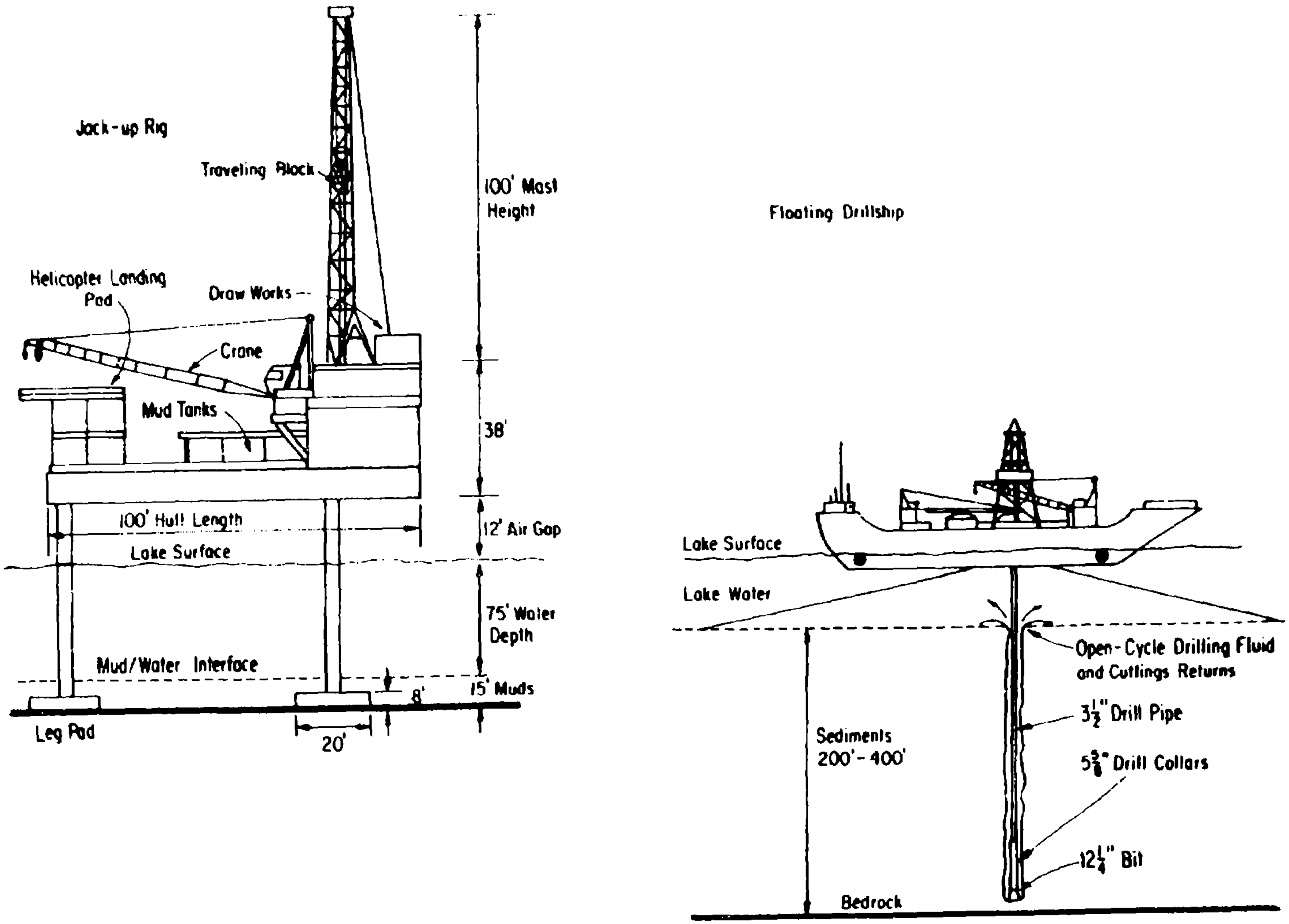

Figure 1-14. Reference Program Jack-up Rig and Floating Drillship Positioned Onsite. The floating drillship is in the process of drilling an open-cycle surface hole.

Table 1-22. Drilling Program for Jack-up Rig (Ohio Clinton-Medina Well Used As An Example)

A. Site Preparation

1. After triangulation surveys are made, the wellsite is marked with either a buoy or passive sonar reflectors (on lakebed).

2. Significant topographic gradients must be smoothed and bottom obstructions removed before the rig is placed onsite.

B. Moving Onsite and Rig-up (Fig. 1-15a)

1. The rig is towed in and positioned.

2. Legs are extended into muds and the rig is jacked 10-12 ft out of the water.

3. A 48-in. × 5-ft wellhead cellar (caisson) is set into the lakebed to serve as a protective cellar for the wellhead.

   a. If well location is on soft sediments, the caisson may be jetted in.

   b. If well location is over cemented sediments or exposed bedrock, the caisson is set in position after drilling a ≥ 5-ft diameter hole with a large bit using open-cycle technology.

4. A 16-in. drive pipe is driven into the mud until refusal (25 strokes/ft).

C. Drilling the Surface Hole (Fig. 1-15b, c)

1. An 11-in. hole is drilled 40 ft into competent bedrock (Middle Devonian shales, approximately 400 ft deep in Ohio). Wellbore washout will cause a 75% increase in volume of cuttings generated over calculated wellbore volume.

2. Water used to drill the surface hole is displaced with gel (bentonite)-water mud. All returns will go into the mud pit located aboard the rig. During drilling, bentonite is used in the surface hole to strengthen uncased wellbore walls in an attempt to keep the hole from caving in and to seal off porous zones to prevent lost circulation; it is also used while casing is run into the hole.

3. A string of 8-5/8-in., K-55, 32 ppf, Range II, short threading and coupling (ST&C) casing (with float shoe and baffle collar) is run into the hole and cemented. The casing will displace 29 bbl of mud to the pits as it is run into the hole.

   a. The float shoe is welded to the baffle collar; the baffle collar and the first and second joints of the casing are made up with Baker-Loc. Centralizers are installed on every fourth joint.

b. A string of 8-5/8-in. casing is run into the hole and set in place 5 ft below the mudline with a 10-3/4-in. riser pipe extending to the rig floor. Water (80 bbl) is pumped into wellbore ahead of cement; either of the following cements is used: API Class H with 4%* bentonite and 2%* calcium chloride ($CaCl_2$), or API Class C with 3%* $CaCl_2$.

4. A combination 10-3/4 × 8-5/8-in. bottom wiper plug is run ahead of the cement to keep it from contaminating the mud. A similar 10-3/4 × 8-5/8-in. top wiper plug is run behind the cement.

5. All excess cement will return between the 10-3/4-in. riser pipe and the 16-in. drive pipe; the riser annulus can be cleaned out to the wellhead with a 2-in. kill line; fluid cement is dumped in the mud pit where the shale shaker, desander, and desilter will remove the cement from the mud.

6. After the second plug bumps, the wellbore pressure is increased to 1000 psi and released; if float shoe and baffle collar leak, the wellbore is repressured to 140 psi and held for 2 hours. Pressure is released and tension is pulled on the casing for 8 hours; the cementing head is then backed off the landing joint.

7. After 2 hours from the time the second plug bumps, divers are sent to cut off the 16-in. drive pipe.

8. Blowout prevention (BOP) equipment is installed on top of the 10-3/4-in. riser pipe below the rig floor; the BOP stack is pressure tested to 2000 psi prior to the drilling out the float shoe.

D. Drilling the Production Hole (Fig. 1-15 d,e)

1. A drill string with a 6-1/4-in. bit is run into the hole; cement is drilled out to 10 ft below the float shoe.

2. The formation is pressure tested to 145 psi.

   a. If the formation breaks down, the pressure is recorded and the company representative is notified.

   b. If no pressure buildup occurs, the hole is recemented with 50 sacks of Class H cement and 25 lb/sack gilsonite (or other fluid-loss additive) plus 2%* $CaCl_2$.

3. A 6-1/4-in. hole is drilled to total depth. If no gas is encountered, the mud system will consist of a lake water/$CaCl_2$ solution to minimize dissolution of salt zones. If a significant gas show occurs, the mud is changed over to a polybrine system.

4. After total depth is reached, the hole is cleaned by circulating 150 bbl of brine ($CaCl_2$ mud).

5. Drill stem tests are performed as required by geologist.

6. Logs are run as required (including caliper log).

7. If the well is productive, it is completed according to the description in Section E below. If the well is dry, it is plugged and abandoned as described below in Section F.

E. Completing the Producing Well

1. The drill string is pulled out of the hole with caution given to keeping the wellbore filled with drilling fluid.

2. A string of 4-1/2-in. K-55, 9.50 ppf, Range II, ST&C casing (with float shoe and baffle collar) is run into the hole and cemented into place.

   a. The float shoe is welded to the baffle collar; the baffle collar and the first, second, and third joints of casing are made up with Baker-Loc. Centralizers are installed on every fourth joint. One cement basket is placed 100 ft above the Clinton-Medina; another cement basket is placed just above the 8-5/8-in. casing shoe.

   b. The 4-1/2-in. casing is landed in the casing flange using a 4-1/2-in. landing string extending to the rig floor.

3. Water (100 bbl) is pumped ahead of either Class H or Class C cements; hole volume from caliper logs will determine the amount of cement required; additional cement sufficient to fill 20 ft of casing is added to the well.

   a. Wiper plugs (4-1/2-in.) are run ahead and behind the cement; the cement is displaced with water. When the top plug bumps, the hole is pressurized to 2000 psi and held for 2 min. Pressure is released to check the float shoe.

      i. If the shoe holds, the landing string is released and the wellhead is circulated clean. All returns will come up the landing string-riser pipe annulus to the mud pit.

      ii. If the shoe leaks, the hole is pressured to 900 psi and held for 2 hours. A 2-in. kill string is run down the annulus; excess cement is circulated out to the mud pit. After 2 hours, tension is released and the landing string is released and removed.

4. Production tubing (2-3/8-in.) is run into the hole to total depth; 100 bbl of the following completion fluid is pumped into the well: water with 2%** potassium chloride (KCl), 0.15%** oxygen scavenger, 0.6%** amine coating.

5. The completion fluid is followed with 15% hydrochloric acid (HCl) plus proper additives; the HCl is spotted across the zone to be perforated.

6. The BOP equipment and riser pipe are removed.

7. The tubing is pulled up to the rig floor. The wellhead is made up on the end of the tubing and run back down to the cellar; the production packer is set and the wellhead is snapped into place. Passive sonar reflectors are positioned around the wellhead for relocation and reentry. A force of 3000 lb of tension is exerted on the wellhead to check its connection. (Note: Tubing must be spaced out so tailpipe is at least 15 ft above the top of the perforation zone.)

8. An annulus line is run to the annulus valve on the wellhead; the tubing and annulus lines are pressure tested to 2000 psi against closed tubing and annulus valves. Valves are opened and the tubing and annulus lines are again tested to 2000 psi. (Note: Casing may burst if a poor cement job was performed. A company representative should examine the bond log and recement if necessary.)

9. Pressure is released and the well is swabbed down to 450 ft.

10. A perforation gun is run into the hole on a wireline through a lubricator at the rig deck; all zones are perforated in one trip.

11. The well is flowed or swabbed in.

F. Plugging and Abandonment Procedure (Fig. 1-15f)

1. Balanced plugs of approximately 300 ft of cement (50 ft above and below each possible producing zone) are set in the wellbore; a 100-ft cement plug is placed at the surface.

2. American Petroleum Institute Class H cement with 2%* $CaCl_2$ is used; balanced plug volumes are calculated using an excess cement factor of 1.75† to account for a 75% increase in drilled hole volume due to anticipated wellbore collapse.

G. Rigging-down and Moving Off (Fig. 1-15g,h)

1. For producing wells, annulus and tubing lines are pulled out of the water.

2. If problems in rig stability are encountered while pulling out of sediments, all bulk materials, drilling fluid, and excess diesel fuel are offloaded from rig to a service barge.

3. The rig is jacked down and its legs are jetted out of the sediments.

4. The rig is towed to the next location by a service tug.

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*Percentage by weight of cement.

**Percentage by volume of completion fluid.

†Not applicable when a depleted well is plugged and abandoned after depletion because plugs are set inside 4-1/2-in. casing with a known volume per foot.

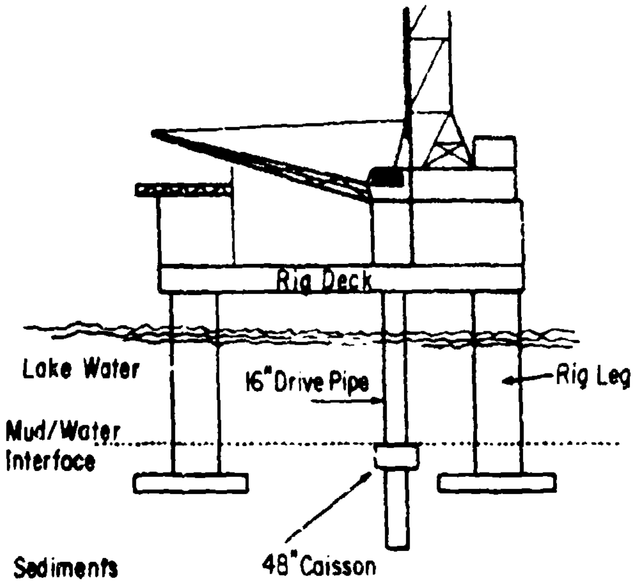

Figure 1-15a. Jack-up Rig Positioned Onsite with Drive Pipe and Wellhead Cellar (Caisson) in Place.

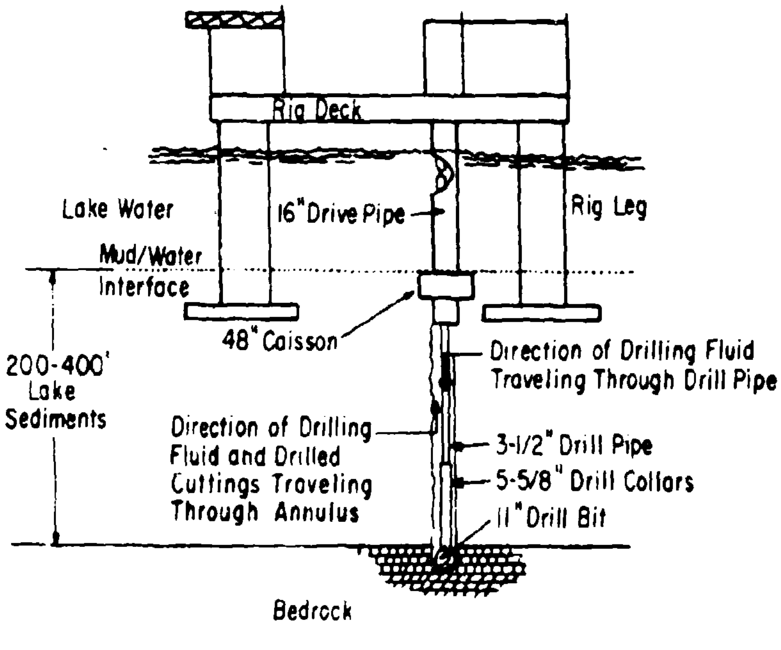

Figure 1-15b. Jack-up Rig in the Process of Drilling a Development Well Surface Hole into Consolidated Bedrock.

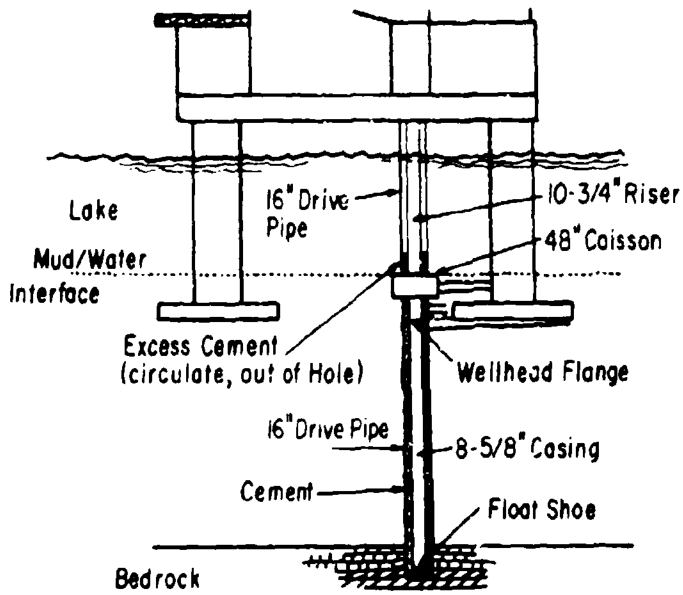

Figure 1-15c. Surface Casing Cemented in Place in a Development Well.

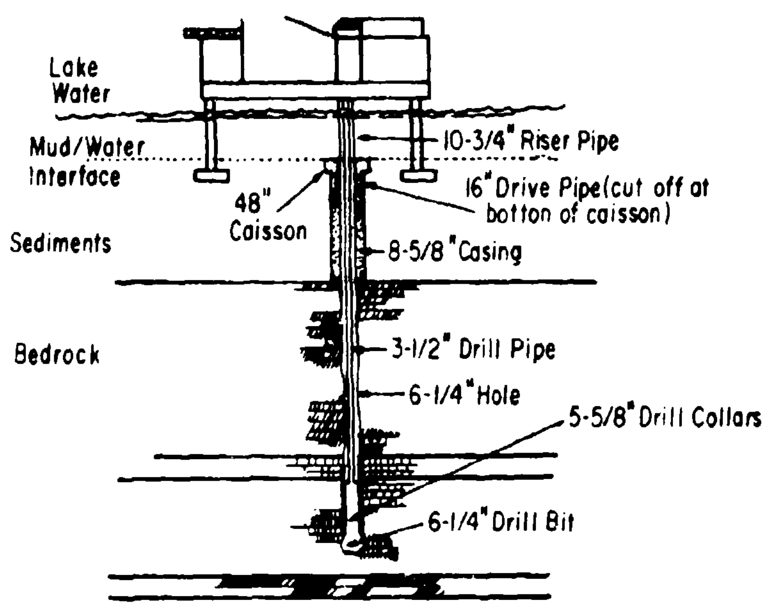

Figure 1-15d. Jack-up Rig in the Process of Drilling a Production Hole to Total Depth.

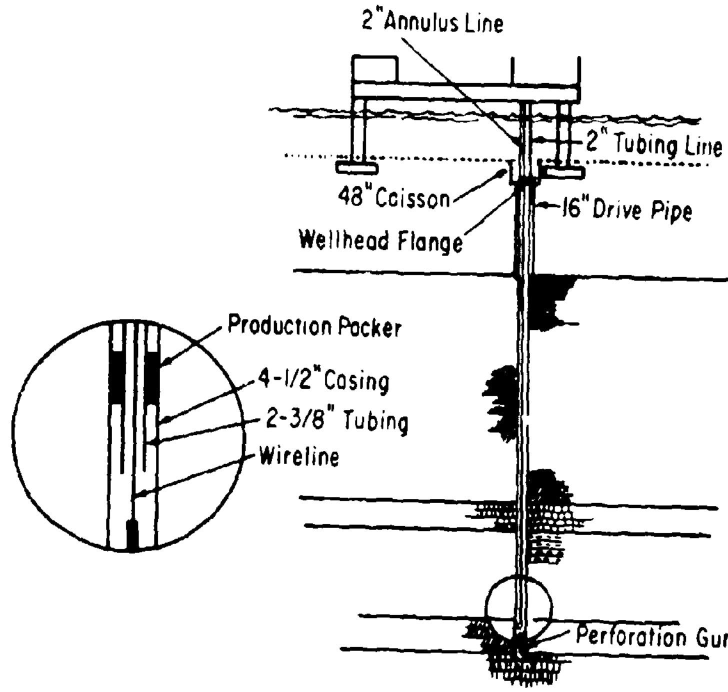

Figure 1-15e. Jack-up Rig in the Process of Perforating a Potential Development Well Producing Zone.

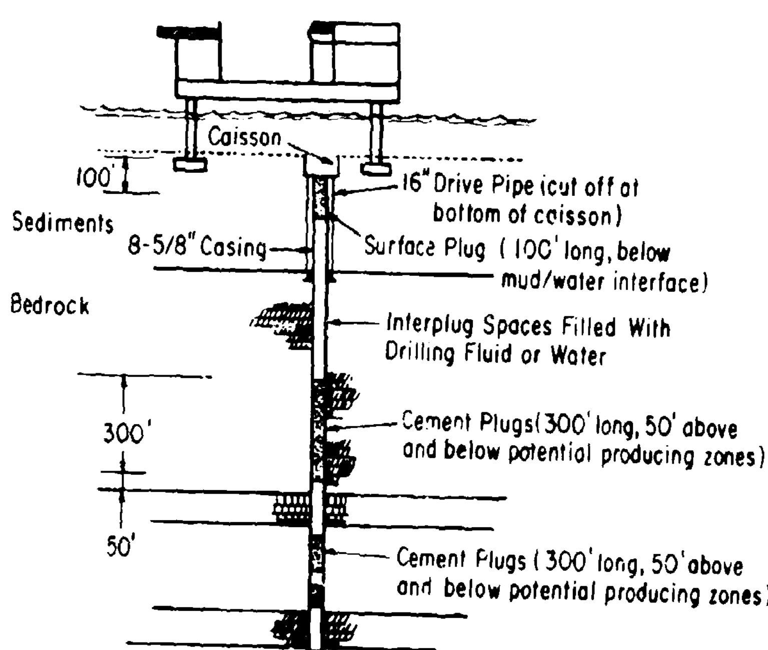

Figure 1-15f. Jack-up Rig Prior to Moving Offsite from a Plugged and Abandoned Well.

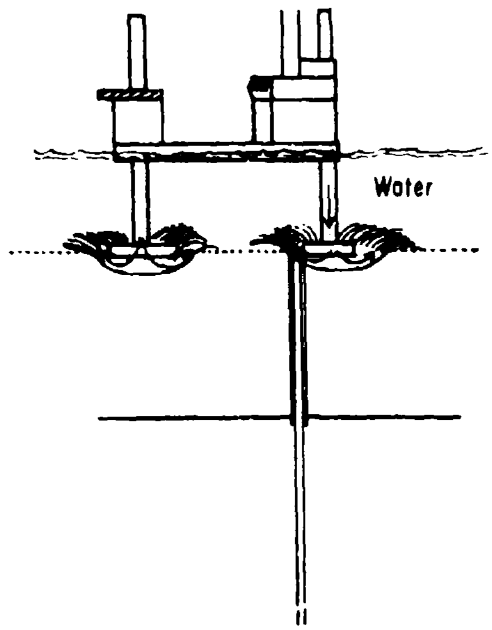

Figure 1-15g. Jack-up Rig in the Process of Jetting Out of the Lakebed.

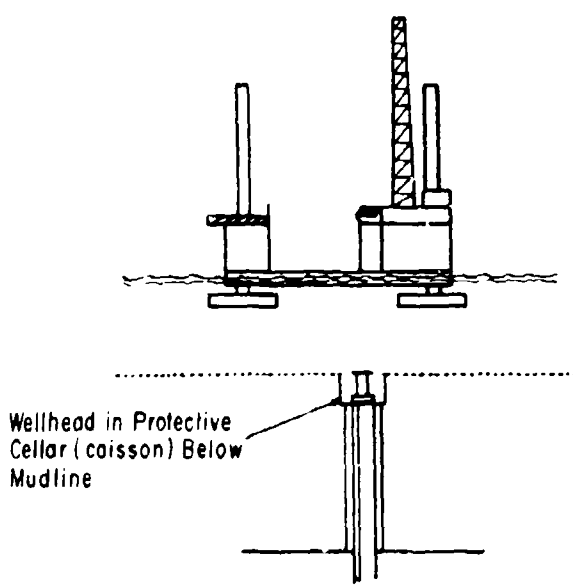

Figure 1-15h. Jack-up Rig with Legs Withdrawn, Awaiting Towing and Positioning at New Drill Site.

Figure 1-15. Sequence of Events for Jack-up Rig Drilling Program.

Table 1-23. Drilling Program for Drillship (Ohio Clinton-Medina Well is Used As an Example)

A. Site Preparation

1. After triangulation surveys are made, the wellsite is marked with either a buoy or passive sonar reflectors (on lakebed).

2. Since a drillship floats over the wellsite, no topographic adjustments need to be made before positioning the rig.

B. Moving Onsite and Rigging-up

1. The rig is towed in and positioned onsite.

2. Anchors are set by support tugs; a turret-type anchoring system allows the vessel to change headings while drilling.

3. A 48-in. × 5-ft wellhead cellar (caisson) can be set if there is a significant danger of wellhead damage from ice or dragging anchors. The Reference Program assumes that where floating rigs are used, water depths are great enough to diminish the danger of damage to wellheads from anticipated causes and, consequently, caissons are not needed. Also, sediments at well sites serviced by floaters will often times not be able to accept a caisson because of their fluid, nonconsolidated nature.

C. Drilling the Surface Hole

1. A 12-1/4-in. hole is drilled through lake sediments and into 10 ft of consolidated bedrock (Upper Devonian shales), using open-cycle technology.

2. Upon reaching the casing depth, water used in drilling is displaced by a gel (bentonite)-water mud prior to running the casing into the hole. During drilling, bentonite is used in the surface hole to strengthen uncased wellbore walls in an attempt to keep the hole from caving in and to seal off porous zones to prevent lost circulation; it is also used while casing is run into the hole.

3. A string of 9-5/8-in., K-55, 36 ppf, Range II, short threading and coupling (ST&C) casing (with sawtooth bottom collar) is run into the hole and cemented into place.

   a. A casing bowl is set at the bottom of the 5-ft caisson using 5-5/8-in. drill collars extending to the rig deck.

   b. Water (60 bbl) is pumped into the wellbore ahead of cement; either of the following cements are used: American Petroleum Institute (API) Class H with 4%* bentonite and 2%* $CaCl_2$, or API Class C with 3%* $CaCl_2$.

c. Twenty feet of cement is left in the casing and held under 70 psi of pressure for 2 hours; pressure is released only after the cement is displaced.

d. A 2-in. kill line can be run to the caisson so that excess cement may be circulated out.

e. A diver is sent to remove the drill collar clamp after 2 hours; the drill collars are then pulled back to the surface.

4. The following operations are performed while waiting for the cement to set (approximately 6 hours).

   a. A string of 3-1/2-in. drill pipe with a landing sub is made up; the string is stabbed into the casing bowl with the aid of a diver.

   b. A blowout prevention (BOP) stack, 10-3/4-in. conductor pipe, and slip joint assembly is stripped over the 3-1/2-in. string and stabbed into the casing bowl; a diver connects the assembly using a swing-bolt clamp.

   c. A 10-3/4-in. rotating head is connected to the top of the slip joint assembly.

   d. The BOP stack and rotating head are pressure tested to 100 psi prior to drilling out the float shoe.

5. The cement is drilled out with an 8-3/4-in. bit; a hole is drilled to the casing point as determined by a geologist (this depth will be a maximum of 400 ft in Ohio-Middle Devonian shales).

6. Water used to drill the hole is displaced with gel-water mud prior to running the casing into the hole.

7. A string of 7-in., K-55, 23 ppf, Range II, ST&C casing (with float shoe and baffle collar) is run into the hole and cemented into place.

   a. The float shoe is welded to the baffle collar; the baffle collar and the first and second joints of the casing are made up with Baker-Loc. One cement basket is placed above any water zone.

   b. The 7-in. casing should be set so that the float shoe is about 6 ft above the bottom of the hole when the casing is landed in the 9-5/8-in. casing bowl; a 7-in. landing string extends from the casing bowl to the rig floor.

   c. The casing string is cemented with either of the following cements: API Class H with 4%* bentonite and 2%* $CaCl_2$, or API Class C with 3%* $CaCl_2$.

d. Excess cement can be circulated out of the 10-3/4 × 7-in. annulus with a 2-in. kill line.

e. After the top wiper plug bumps, the wellbore pressure is increased to 1000 psi and released; if the float shoe and baffle collar leak, the wellbore is repressured to 120 psi and held for 2 hours. Pressure is released and tension is pulled on the casing for 8 hours; the cementing head is then backed off the landing joint.

D. Drilling the Production Hole

1. After 8 hours of waiting for the cement to set, a 6-1/4-in. hole is drilled through the cement to 10 ft below the float shoe; the formation is pressure tested to 140 psi.

   a. If the formation breaks down, the pressure is recorded and the company representative is notified.

   b. If no pressure buildup occurs, the hole is recemented with 50 sacks of Class H cement and 25 lb/sack gilsonite (or other fluid-loss additive) plus 2%* $CaCl_2$.

2. A 6-1/4-in. hole is drilled to total depth. If no gas is encountered, the mud system will consist of a lake water/$CaCl_2$ solution to minimize dissolution of salt zones. If a significant gas show occurs, the mud is changed over to a polybrine system.

3. After total depth is reached, the hole is cleaned by circulating 150 bbl of brine ($CaCl_2$ mud).

4. Drillstem tests are performed as required by geologist.

5. Logs are run as required (including caliper log).

6. If the well is productive, it is completed according to the description in Section E below. If the well is dry, it is plugged and abandoned as described below in Section F.

E. Completing the Producing Well

1. The drill string is pulled out of the hole with caution given to keeping the wellbore filled with drilling fluid.

2. A string of 4-1/2-in., K-55, 9.50 ppf, Range II, ST&C casing (with float shoe and baffle collar), is run into the hole and cemented into place.

3. Water (100 bbl) is pumped ahead of either Class H or Class C cements; hole volume from caliper logs will determine the amount of cement required; additional cement sufficient to fill 20 ft of casing is added to the well.

a. Wiper plugs (4-1/2-in.) are run ahead and behind the cement; the cement is displaced with water. The plug is bumped and the hole is pressurized to 2000 psi and held for 2 min. Pressure is released to check the float shoe.

   i. If the shoe holds, the landing string is released and the wellhead is circulated out. All returns will come up the landing string-riser pipe annulus to the mud pit.

   ii. If the shoe leaks, the hole is pressured to 900 psi and held for 2 hours. A 2-in. kill string is run down the annulus; excess cement is circulated out to the mud pit. After 2 hours, tension is released and the landing string is released and removed.

4. Production tubing (2-3/8-in.) is run into the hole to total depth; 100 bbl of the following completion fluid is pumped into the well: water with 2%** KCl, 0.15%** oxygen scavenger, 0.5%** amine coating.

5. The completion fluid is followed with 15% HCl plus proper additives; the HCl is spotted across the zone to be perforated.

6. The BOP and riser pipe are removed.

7. The tubing is pulled up to the rig floor. The wellhead is made up on the end of the tubing and run back down to the cellar; the production packer is set and the wellhead is snapped into place. Passive sonar reflectors are positioned around the wellhead for relocation and reentry. A force of 3000 lb of tension is exerted on the wellhead to check its connection. (Note: Tubing must be spaced out so tailpipe is at least 15 ft above the top of the perforation zone.)

8. An annulus line is run to the annulus valve on the wellhead; the tubing and annulus lines are pressure tested to 2000 psi against closed tubing and annulus valves. Valves are opened and the tubing and annulus lines are again tested to 2000 psi. (Note: Casing may burst if a poor cement job was performed. A company representative should examine the bond log and recement if necessary.)

9. Pressure is released and the well is swabbed down to 450 ft.

10. A perforation gun is run into the hole on a wireline through a lubricator at the rig deck; all zones are perforated in one trip.

11. The well is flowed or swabbed in.

F. Plugging and Abandonment Procedure

1. Balanced plugs of approximately 300 ft of cement (50 ft above and below each possible producing zone) are set in the wellbore; a 100-ft cement plug is placed at the surface.

2. API Class H cement with 2%* $CaCl_2$ is used; balanced plug volumes are calculated using an excess cement factor of 1.75† to account for a 75% increase in drilled hole volume due to anticipated wellbore collapse.

G. Rigging-down and Moving Off

1. After a well is plugged and abandoned or completed, the anchors are pulled and the ship is towed to the next location.

2. On the drillship, there is no need to offload bulk materials or drilling fluids because there is no jacking procedure and because the ship is relatively stable under tow.

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*Percentage by weight of cement.

**Percentage by volume of completion fluid.

†Not applicable when a depleted well is plugged and abandoned after depletion because plugs are set inside 4-1/2-in. casing with a known volume per foot.

1.097
Potentially productive wells are scheduled for acidization or hydraulic fracturing (stimulation); a stimulation barge (see Appendix B, Table B.4) is towed to the well site and divers connect high-pressure lines between the barge and underwater wellhead. Fluids and gases are pumped into the gas-bearing formation in hopes of increasing reservoir permeability and, consequently, the amount of gas produced. To ensure efficient well testing and optimum production of gas, all fluids injected into the formation must be eventually removed. Reference Program assumptions concerning stimulation procedures are based upon Canadian offshore development experience in Lake Erie. In order to minimize release of stimulation fluids to the Lake, the bulk of these fluids are returned under the force of injection pressure and are collected aboard the barge until a relatively low flow results (10 gal/min). Canadian operators argue that there is a potential for an explosion as increasing amounts of natural gas accompany the fluid returns to a gas/liquid separator aboard the stimulation barge (McGregor et al. 1978). This explosion potential, together with the economic burden of maintaining a barge onsite to recover only small volumes of liquid returns after the 10 gal/min flow rate is achieved, serve as the basis for operational assumptions in the Reference Program.

1.098
After a large portion of the injected fluids are returned and collected and flow rates decrease to 10 gal/min, divers switch the return lines over to a line buoyed at the lake surface, and the well is allowed to flow open to the atmosphere (on camel) for approximately 12 hours (for discussion of potential environmental impacts, see Chapter Four - Water Quality, Aquatic Ecology, and Air Quality). The stimulation barge carries enough material to fracture or acidize three wells. It also has containers aboard to store liquid returns from these wells. Wastes are brought back to shore and trucked to the waste-treatment/disposal facility.

1.099
After wells are completed and stimulated, a field of 25 wells is interconnected through underwater gathering and trunk lines to one common flowline to shore (see Appendix B, Table B.5). This flowline is designed to carry the maximum volume of gas while maintaining pressures sufficient to transport the gas to shore without compression for as long as possible. In order to calculate gas production rates, each field of 25 wells was assumed to begin production one year after drilling and stimulation.

1.100
Since Reference Program flowlines can transmit gas for up to 20 miles without significant pressure decline problems, only 10 narrow onshore corridors need to be committed to flowline landfalls (see Figure 1-1, map pocket).* Flowlines from each lease area are routed towards the most convenient landfall (Table 1-24). At each landfall, all flowlines are joined into one underground pipe that transmits the gas to the shore facility located inland within 0.5 mile from shore (shore facilities should be prohibited from land/water interface sites in order to minimize land use, esthetic, and potential water

*A 10-mile band centered around each landfall indicates a need to investigate landform and soil conditions to locate an optimal site (i.e., one not constrained by environmental sensitivity and one most suited to pipeline burial at least cost).

Table 1-24. Anticipated Maximum Daily Production of Natural Gas at 10 Landfalls with Shore Facilities in the Reference Program[a]

Landfall	Contributing Lease Areas	Maximum Production per Lease Area (MMCF/day)	Maximum Production per Landfall (MMCF/day)
New York			
1	I	8.2	8.2
2	II	9.8	9.8
3	III	14.4	14.4
Pennsylvania			
4	IV	10.4	10.4
5	V	14.6	14.6
Ohio			
6	VI	13.1	13.1
7	VII	10.8	20.6
	IX	15.1	
8	VIII	12.1	61.3
	XIII	61.3	
	XVI	7.4[b]	
9	X	13.2	21.2
	XI	11.1	
	XII	10.3	
10	XIV	96.7	96.7
	XV	8.6[c]	

[a]See also Figure 1-1 (map pocket).

[b]Will not be produced until XIII is depleted.

[c]Will not be produced until XIV is depleted.

quality impacts); gas from all flowlines is metered and processed before being piped through the existing onland distribution/transmission system. Gas from Clinton-Medina wells is separated from any produced formation liquids, dried to less than 5 lb of water vapor per million cubic feet, and compressed when necessary to meet onland distribution/transmission line requirements.* The

*In the Reference Program, individual flowline pressures decline below regional transmission line pressures (200 psia) by the third year of production; in each lease area, gas from one new field (flowline) is added to total production annually. Although compression should start in the third year of production, when assigning compression costs to lease areas, it was assumed that compression was initiated at the beginning of the third year following lease area production (see Appendix B, Table B.3).

size or output of these compressors will dictate whether or not a Prevention of Significant Deterioration permit will be required. This process plant is described in Appendix B, Table B.6. Lockport reef gas must also be stripped of toxic and corrosive H_2S. Gas-treatment plants (see Appendix B, Table B.7) designed to remove this H_2S are required at the two Reference Program landfalls receiving flowlines from Lockport reefs. At all gas process/treatment plants, an optional glycol injection system has been designed to eliminate anticipated problems of decreased production* from hydrate (water-hydrocarbon ice crystals) formation at wellheads during the winter (Keeley 1978). When sprayed into a wellhead at a rate of 4 to 5 gal/h, the glycol acts as an antifreeze solution to depress the temperature at which crystals would form to below anticipated ambient conditions. Glycol feeder lines would be bundled with gas flowlines under the Lake. Glycol can be recovered from the gas stream at shore and reinjected into feeder lines (for discussion of potential environmental impacts resulting from the use of glycol, see Chapter Four - Water Quality and Water Use).

1.101
Upon depletion of producing wells to economic limits (Lockport wells, 15 years; Clinton-Medina wells, 20 years), an operator could either plug and abandon a well or prepare the well and reservoir for injection-storage. Although a Canadian operator is currently using a depleted Lake Erie reservoir for storage (Reeve-Newson 1979--personal communication) and operators working in U.S. waters may wish to explore storage options in U.S. reservoirs, storage field design requirements and potential impacts from gas storage under the Lake will not be considered in the Reference Program. Depleted wells in all lease areas except XIII and XIV will have wellheads and production tubing removed and cement plugs inserted above and below producing zones as described in Tables 1-22 and 1-23. Wells in Lease Areas XIII and XIV will be recompleted for production of Clinton-Medina gas underlying Lockport reefs; those redrilled Clinton-Medina wells are reassigned to Lease Areas XV and XVI (Table 1-24) in the Reference Program.

Fate of Materials Used and Residuals Generated

1.102
During the course of routine exploration, development, production and decommissioning activities, the materials used to develop and produce gas in some way lose their physical and chemical properties that made them initially useful. Concurrently, residuals are generated (1) from the wellbore as it penetrates lake sediments and geologic formations, (2) during the process of venting or flaring gas, and (3) as a result of fuel combustion on rigs and vessels, and at shore facilities. Table 1-25 lists those activities routinely performed in the Reference Program and describes the fate of materials used and residuals generated. Since the Reference Program has been designed to provide optimum protection of lake resources with available offshore development and production technology, the materials used and residuals generated will be, wherever possible, collected, stored, and relegated to land disposal.

*Canadian experience indicates that up to 20% of gas production can be eliminated from hydrate blockage of wellhead orifices and pipelines (Reeve-Newson 1979--personal communication).

Table 1-25. Fate of Residuals Generated and Materials Used for Routine Activities

Activity	Source of Potential Impact	Fate of Residuals Generated and Materials Used
1. EXPLORATION		
1.1 Seismic Survey[a]	Diesel fuel is combusted on survey vessel	Diesel fuel is combusted and residuals are emitted to atmosphere
	Trash and human wastes are generated on survey vessel	Wastes are stored aboard vessel and disposed onshore
	"Explosion" from air gun is used to measure subsurface geology	Energy from air gun is dissipated to lake water
1.2 Basement Exploratory Wells Drilled	Sources of impacts are the same as development wells except that basement wells are:	See development wells below (2.3-2.5)
	drilled deeper than development wells	More drilling fluids are used than for development wells
	drilled through formations that may contain some liquid hydrocarbons	More cuttings are generated than for development wells A chance exists for cuttings to be contaminated by liquid hydrocarbons in selected Ordovician and Cambrian strata
2. DEVELOPMENT		
2.1 Site Preparation	Significant topographic gradients must be smoothed and bottom obstructions removed before rig is placed onsite	Sediment is not contained and is free to disperse in lake water
2.2 Move Onsite and Rig Up	Sediment is suspended from lakebed when setting rig legs, anchors, caisson, or drive pipe	Sediment is not contained and is free to disperse in lake water
2.3 Drill Surface Hole	Diesel fuel is combusted to power all development activities	Diesel fuel is combusted and residuals are emitted to atmosphere
	Cuttings are generated from the wellbore	Jack-up rig: cuttings are collected and brought to shore for disposal Floating rig: cuttings are not contained and are released to lake water
	Drilling fluids are used in the wellbore	Jack-up rig: fluids are collected, stored aboard, and reused Floating rig: fluids are not contained and are released to lake water
	Cement is used to set casing	Jack-up rig: most cement is left in wellbore and not recovered; all excess cement is collected aboard and brought to shore for disposal Floating rig: most cement is left in wellbore and not recovered; excess cement cannot be contained and is discharged to lake water
2.4 Drill Secondary Surface Hole (floating rig only)	Cuttings are generated from the wellbore	Cuttings are collected and brought to shore for disposal
	Drilling fluids are used in the wellbore	Fluids are collected, stored aboard, and reused
	Cement is used to set casing	Most cement is left in wellbore and not recovered; all excess cement is collected aboard and brought to shore for disposal
2.5 Drill Production Hole	Cuttings are generated from the wellbore	Cuttings are collected and brought to shore for disposal
	Drilling fluids are used in the wellbore	Fluids are collected, stored aboard, and reused

Table 1-25. Continued

Activity	Source of Potential Impact	Fate of Residuals Generated and Materials Used
2.6 Perform Drillstem Test	Formation liquids and natural gas are flowed to the rig and separated; after measurement, natural gas is flared	Formation liquids are collected and brought to shore for disposal Gases are combusted (flared) and residuals emitted to atmosphere
2.7 Plug and Abandon Dry Holes	Cement is used to plug off selected formations	All cement is left in wellbore and not recovered
	Drilling fluid or water is left in wellbore between plugs	All fluid is left in the wellbore
2.8 Complete Potential Producer Well	Cement is used to set production casing	Most cement is left in wellbore and not recovered; all excess cement is collected and brought to shore for disposal
	Completion fluid is added to wellbore to remove any residual contaminants and to prepare well for production	Completion fluid is circulated in the wellbore; excess fluid is returned to the rig and brought to shore for disposal
	Acid and additives are added to the wellbore prior to perforation	Most of the acid and additives migrate to formation after perforation. Some excess acid could return to rig upon well swabbing or to stimulation barge upon fracturing; in either case, acid is collected and brought to shore for disposal
	Well is swabbed down to 450 ft from mud line	Swabbed fluids are collected and brought to shore for disposal
2.9 Stimulate Potential Producer Well	Fracturing fluids and gases are injected into the wellbore; returns are collected and separated into gases and liquids on the barge	Most of the spent fracturing fluid is returned to the stimulation barge, collected, and brought to shore for disposal; gases are vented to the atmosphere
	Return flowline to barge is disconnected and gas and some liquids from the formation are flowed "on camel" to the lake surface	Gas/liquid mist is emitted to the atmosphere; liquids are discharged to the Lake
3. PRODUCTION		
3.1 Flow Gas to Shore	Some produced gas and formation fluids may periodically leak from wellheads and pipeline fittings	Gas and liquids lost from flowlines will be released to the Lake. Some gas and all liquids will dissolve in lake water; some gas will be emitted to the atmosphere
	Wellheads and pipelines will be routinely cleaned and maintained by divers; wells will be shut in, and lines opened, cleaned, and bled to atmospheric pressure	Gas evacuated from lines will be flared at production facilities and combustion residuals emitted to the atmosphere; hydrates and some gas will escape to the Lake during wellhead cleaning
3.2 Gas Processed/Treated Onshore	Some formation liquid will accompany the gas to shore and will be separated from the gas stream at the shore facility	Produced liquids will be disposed of onshore
	H_2S gas from Lockport reefs will be removed from the gas stream and converted to elemental sulfur at shore facilities	Elemental sulfur will be sold commercially; liquid and solid by-products will be disposed of onshore; gaseous SO_2 emissions will be reduced to less than 250 ppm and released to the atmosphere
	Glycol injected into the wellheads to reduce hydrate formation will be recovered from the gas stream at shore facilities	Recovered glycol will be treated, filtered, and reused. Water separated from the glycol will be disposed of onshore. Glycol reboiler will produce steam which will be condensed, recovered, and stored as liquid for disposal onshore

Table 1-25. Continued

Activity	Source of Potential Impact	Fate of Residuals Generated and Materials Used
3.2 Gas Processed/Treated Onshore (cont'd)	Produced natural gas will be used to run compressor engines and glycol reboilers	Gas is combusted and residuals are emitted to the atmosphere
	Small amounts of gas and liquids will periodically leak from valves and fittings in the gas plant	Gas will be emitted to the atmosphere; liquids will drip to the plant floor and/or ground. Oil absorbents are used to clean up spills and must be disposed of
	Reboilers, condensers, storage tanks, and filters are periodically cleaned	Scale, sludge, and filter media must be disposed of
4. DECOMMISSIONING		
4.1 Plug and Abandon Depleted Wells	When wellhead and tubing are removed from the well, small amounts of completion fluid and gas can escape from the well	Gas and completion fluid released from the well will be released to the Lake. Some gas and all liquids will dissolve in lake water; some will be emitted to the atmosphere
	Cement is used to plug and seal off selected formations	All cement is left in the wellbore and not recovered

[a]Has already been completed in U.S. waters of Lake Erie.

The Resource Conservation and Recovery Act (RCRA) and implementation regulations were used to classify wastes generated. Within the bounds established by limited chemical information available on the nature of natural gas development wastes and the tentative status of proposed RCRA regulations, Reference Program wastes are reviewed and classified into one of three possible categories, i.e., hazardous, special, or conventional.* A waste management scheme is suggested for all RCRA wastes.

1.103
Drilling fluids used in the Reference Program consist of two basic ingredients: a viscosifier such as bentonite clay and a weighting agent such as $CaCl_2$. Additional drilling fluid properties may be developed and controlled by the use of additives which function as thinners, alkalinity and pH control agents, surfactants, and defoamers. Many of these additives are organic specialties added to the drilling fluids in small quantities (Sheen Tech. Subcomm. 1976). The various drilling fluids used during well development are presented in Table 1-26, and technical terms describing their functional properties are explained in Table 1-27.

1.104
Spent drilling fluid will contain drilled shales and minerals as well as geologic formation fluids such as brines or hydrocarbons. Other possible components include rig wash compounds, deck drainage, spills of diesel fuel and lubricating oils, and drilled cement (Shaw 1975). The composition of the drilling fluid may be intentionally varied during the course of drilling a single well in order to accommodate changing conditions encountered by the

*Non-RCRA wastes are assumed to be conventional in the sense that nonhazardous sanitary landfill laws and regulations are adequate.

Table 1-26. Chemical Composition of Reference Program Drilling Fluids

Component[a]	Functional Property	Chemical Concentration (lb/bbl) Gel-Water Mud	$CaCl_2$ Mud	Polybrine Mud
Bentonite	Viscosifier	20	10	--
$CaCl_2$	Weighting material, alkalinity and pH control additive, shale control inhibitor	--	140	170
Starch	Fluid loss reducer	--	5	--
Polybrine	Viscosifier, fluid loss reducer	--	--	3
Ceastop (unspecified polymer and $CaCO_3$)[b]	Fluid loss reducer, lost circulation material, viscosifier	--	--	5
Mixical ($CaCO_3$-based formulation)[b]	Fluid loss reducer, loss circulation material	--	--	5
Magconol (alcohol-based)	Defoamer	--	--	0.25

[a]Polybrine, Ceastop, Mixical, and Magconol are registered trademarks of Magcobar Operations, Oilfield Products Group, Dresser Industries, Inc. [see listing by Wright (1978)].

[b]Composition from industry sources, but not from manufacturer.

Abbreviations: $CaCl_2$ = calcium chloride; $CaCO_3$ = calcium carbonate.

drill bit as it penetrates different geologic strata with different properties (Sheen Tech. Subcomm. 1976). Although there may be several hundred drilling chemicals listed by trade name, there are only 45 to 50 compounds in use in drilling fluids (Ray 1978; McMordie 1975). The composition of many of the additives is proprietary, and the drilling fluids file published by the industry lists most of them by trade names with no indication of chemical formulas (Fritsch 1975). It has been noted that the organic additives in 1968 comprised less than 3% (by weight) of all drilling fluid material sales (Sheen Tech. Subcomm. 1976), so they are a very small portion of the whole drilling-fluid disposal problem in terms of mass and volumes, although not necessarily a small problem in terms of toxicity. Additives used in one representative drilling fluid are listed in Table 1-28.

1.105

In principle, the spent drilling fluid from a closed-cycle drilling operation may be treated with various additives in order to render it suitable for reuse. Such reconditioning has been standard practice with oil-based drilling fluids for economic reasons; water-based fluids, such as those proposed for use in the Reference Program, have generally been discharged overboard in

Table 1-27. Chemical and Physical Properties of Fluid Components[a]

Alkalinity and pH control additives	Chemicals used to control the degree of acidity or alkalinity of a fluid, e.g., lime, caustic soda, and bicarbonate of soda.
Bactericides	Components that reduce the bacteria count, e.g., paraformaldehyde, caustic soda, lime, and starch preservatives.
Calcium removers	Chemicals that counteract the contaminating effects of the anhydrite and gypsum forms of calcium sulfate, e.g., caustic soda, soda ash, bicarbonate of soda, and certain polyphosphates.
Carrying agents	A fluid, often a gas, that is used to hydraulically transmit pressure to the producing formation during a fracturing operation, e.g., nitrogen or carbon dioxide.
Corrosion inhibiters	Additives that check corrosion either by scavenging oxygen (i.e., they are reducing agents) or by forming a protective film, e.g., sodium sulfite, sodium arsenite, and various amines.
Defoamers	Products designed to reduce foaming action, particularly that occurring in muds containing brines. Constituents include sodium alkylaryl sulfonate, aluminum sulfonate, aluminum stearate, alcohol compounds, and silicones.
Emulsifiers	Surfactants that create a heteorgeneous mixture of two immiscible liquids by causing one liquid phase to become finely dispersed in the other. Constituents include ferro and chrome lignosulfonates, lignite, bentonite, carboxymethyl hydroxyethyl cellulose, polyanionic cellulosic polymers, and amine-based compounds.
Flocculants	Additives that cause suspended colloidal particles to group together into bunches ("flocs") and thus settle out of the suspension, e.g., salt, hydrated lime, gypsum, and sodium tetraphosphate.
Fluid loss reducers	Components that reduce the tendency of the liquid phase of the drilling fluid to pass into the formation, e.g., bentonite clays, sodium carboxymethylcellulose, and pregelatinized starch.
Foaming agents	Surfactant chemicals that foam in the presence of water, thus permitting air or gas drilling through water-producing formations. Constituents include nonionic emulsifiers, anionic foaming agents, asphaltic materials, potassium lignite derivatives, and detergents.
Formation dissolvers	Acid solutions that are used to dissolve formation materials such as limestone and dolomite during well completion and stimulation in order to promote the flow of gas. Hydrochloric acid (typically 15 to 28% solutions), formic acid, and acetic acid have all been used for this purpose.
Lost circulation materials	Additives used to plug the zone of loss in the formation away from the face of the bore hole, so that subsequent operations will not disturb the plug, e.g., walnut shells, ground mica, and cellophane.
Lubricants	Specialty chemicals used to reduce torque and increase horsepower at the drill bit by reducing the coefficient of friction. They are also often used to free stuck pipe. Certain oils, graphite powder, and soaps are common drilling lubricants.
Proppants	Small-grained chemically unreactive solid materials that during the hydraulic fracturing process are forced into the fractures created in the producing formation to keep them open. Common propping agents are sand and glass beads.
Shale control inhibitors	Substances that are used to control caving by swelling or hydrous disintegration of shale, e.g., gypsum, sodium silicate, calcium lignosulfonate, lime, and salt.
Surfactants	Chemicals that reduce the interfacial tension between contacting surfaces (water/oil, water/solid, water/air, etc). These may sometimes be emulsifiers, deemulsifiers, flocculants, or deflocculants, depending on the surfaces involved.
Thinners and dispersants	Chemicals that modify the relationship between the viscosity and percentage of solids in a drilling mud by preventing or reversing the random association of suspended solid particles. Tannins, polyphosphates, and lignitic materials are often chosen as thinners and dispersants.
Viscosifiers	Colloidal materials that are employed as viscosity builders for fluids to assure a high viscosity-solids relationship, e.g., bentonite, carboxymethyl cellulose, and attapulgite clays.
Weighting materials	Materials used to control formation pressures, check caving, facilitate pulling dry pipe, and reduce some types of circulation loss, by increasing the density, e.g., barite, certain lead compounds, and iron oxides.

[a]Based on Wright (1978) except: carrying agents (information from staff consultants); formation dissolvers and proppants (Hurst 1970).

Table 1-28. Chemical Composition of Representative Drilling Fluid Additives[a]

Component	Functional Property	Chemical Concentration (lb/bbl)
Barite ($BaSO_4$)	Weighting material	70
Caustic (NaOH)	Alkalinity and pH control	--
Chrome and ferrochrome lignosulfonate	Thinner and dispersant	2
Lignite	Thinner and dispersant emulsifier, fluid loss reducer	0.1
Lime (CaO)	Alkalinity and pH control	0.15
Sodium acid pyrophosphate (SAPP)	Thinner and dispersant, calcium remover	[illegible].1
Soda ash (Na_2CO_3)	Calcium remover	0.15

[a]Data from Sheen Technical Subcommittee (1976). Quantities refer to a drilled depth of 2463 ft; 3260 bbl of mud was generated with a bentonite usage of 15 lb/bbl.

Abbreviations: $BaSO_4$ = barium sulfate; NaOH = sodium hydroxide; CaO = calcium oxide; Na_2CO_3 = sodium carbonate.

unspecified quantities at unspecified intervals, usually to provide "mud-pit" capacity for the addition of water and additives to change the drilling fluid properties (Simpson 1975; Ray 1978). In the absence of suitable data concerning the length of time that water-based drilling fluids can be reused prior to disposal, it is assumed that none of the drilling fluid from a particular drilling activity will be reused. This worst-case estimate of drilling fluid volume generated per well and collected for disposal onshore is presented in Table 1-29.

1.106
Deck drainage generally consists of a composite of substances which collect on rig decks from sources such as drilling equipment, deck washings, and rain (USEPA 1979). It is assumed that approximately 40 gal/day of deck drainage will be produced during the development of a well, and that most of this will consist of drilling fluids and water with at most 1 gal per well of oil and grease. The total quantity per well is presented in Table 1-29.

1.107
The three categories of waste liquids (i.e., completion fluid, spent acid, and stimulation returns) are of relevance only for producing holes. The Reference Program completion fluid is an aqueous solution containing KCl and small quantities of two corrosion inhibitors--one an oxygen scavenger, the other an amine which forms a protective film over surfaces. The acidizing fluid which is sent downhole consists of 15% hydrochloric acid with small quantities of corrosion inhibitors and retarders. The stimulation fluid consists of water

Table 1-29. Quantities of Wastes Produced by Each Typical Reference Program Well

Type of Well	Drilling Fluid (ft^3)	Deck Drainage (ft^3)	Completion Fluid (ft^3)	Spent Acid[a] (ft^3)	Stimulation Returns (ft^3)	Drill Cuttings (ft^3)	Sanitary Wastes (ft^3)	Excess Cement (ft^3)	Domestic Wastes (lb)
PRODUCING HOLE									
<u>Jack-up</u>									
New York	2358	35	219	62	2540	1340	4345	60	1324
Pennsylvania	2712	44	84	76	2540	1840	5548	60	1674
Ohio	2892	47	45	81	2540	2137	5882	60	1794
<u>Drillship</u>[b]									
New York	2375	43	219	62	2540	1134	5214	90	1539
Pennsylvania	2644	50	84	76	2540	1502	6216	90	1856
Ohio	2740	52	45	81	2540	1562	6550	90	1976
DRY HOLE									
<u>Jack-up</u>									
New York	2358	28	--	--	--	1340	3543	30	1144
Pennsylvania	2712	38	--	--	--	1840	4746	30	1442
Ohio	2892	41	--	--	--	2137	5080	30	1705
<u>Drillship</u>[b]									
New York	2375	43	--	--	--	1139	5214	60	1547
Pennsylvania	2644	50	--	--	--	1502	6216	60	1812
Ohio	2740	52	--	--	--	1562	6550	60	1921

[a]Total quantities of spent acid include 300 to 400 gal of formation water per well in addition to the 165 gal of returned acidizing solution.

[b]The primary surface hole must be drilled in an open-cycle mode; drilling fluids and cuttings cannot be collected and are released to the Lake (see Table 1-23).

containing unspecified amounts of guar gum and other unidentified chemicals, the most offensive being various surfactants and emulsifiers. The guar gum, a natural product which imparts viscosity to the aqueous system and reduces friction in the pumping equipment, was by far the most commonly used fracturing additive several years ago (Hurst 1970). The composition of these fluids in the Reference Program is given in Table 1-30 and the total quantities generated per well are given in Table 1-29.

1.108
Drill cuttings are composed of the rock, fines, and liquids contained in the geologic formations that have been drilled. These may consist of silts (2-74 μm), sands (>74 μm), limestones, anhydrites, shales, and other drilled solids (Allred 1975). The exact make-up of the cuttings varies from one drilling location to another (USEPA 1976). Drilling fluid may adhere to the cuttings to the extent of 1 to 5% by volume, but most of the fluid washes off during the discharge of cuttings in open-cycle operation (Ray 1978), and would presumably wash off during solid-liquid separation processes in closed-cycle operation.

1.109
The sanitary wastes from offshore gas drilling facilities are composed of human body waste. The domestic waste will consist of garbage and trash such

Table 1-30. Chemical Composition of Miscellaneous Fluids and Materials Used in Reference Program Development Activities

Component	Functional Property	Chemical Concentration
Completion Fluid[a]		
Potassium chloride (KCl)	Corrosion controller	7 lb/bbl
Oxygen scavenger (e.g., sodium sulfite, Na_2SO_3)	Corrosion inhibitor	0.05 gal/bbl
Filming amine (e.g., (abietylamine)	Corrosion inhibitor	0.24 gal/bbl
Acidizing Fluid[a]		
Hydrochloric acid (HCl)	Formation dissolver	15% (by weight)
Unidentified	Corrosion inhibitor	1% (by weight)
Fracture Fluid[a]		
Potassium chloride (KCl)	Shale control inhibitor	3% solution
Unidentified	Surfactant	1 gal/1000 gal
Unidentified	Bactericide	0.1 gal/1000 gal
Frac gel	Viscosifier	30-60 lb/1000 gal
Unidentified	Fluid loss additive	30 lb/1000 gal (concentration highly variable)
Unidentified	Clay stabilizer	1 gal/1000 gal (optional; controls swelling clays in producing formation)
Unidentified	Cross linker	0.6 gal/1000 gal
Unidentified	Friction reducer	5 lb/1000 gal
Ancillary Fracture Materials		
Sand	Proppant	1-3 lb/gal fracture fluid
Nitrogen gas	Carrying agent	240 MCF

[a]In addition to water.

as kitchen and general housekeeping wastes as well as rig garbage such as empty bulk material sacks. There will also be small quantities of excess cement from the drilling operation (USEPA 1976). The quantities of these wastes predicted for Reference Program wells are presented in Table 1-29. Note that the volumes of sanitary wastes are relatively large when compared to the volumes of the other wastes.

1.110
The formation waters are aqueous solutions, often brines, which are produced from the geologic formations encountered during the drilling of gas wells and which continue to be produced during the subsequent production of natural gas. The composition of these waters varies, but, as an example, a composite of formation water samples taken from an onshore natural gas production facility servicing offshore Canadian Lake Erie wells contained approximately 2.6×10^5 mg/L total dissolved solids. The reported cations consisted of

sodium (5.2×10^4 mg/L), calcium (3.6×10^4 mg/L), and magnesium (6.3×10^3 mg/L). The reported anions were chloride (1.6×10^5 mg/L) and sulfate (2.9×10^2 mg/L). Barium, carbonate, and bicarbonate ions were not reported (Reeve-Newson 1979--personal communication). Relatively little of the formation water appears as waste during the development phase of the Reference Program; 300 to 440 gal are expected with the stimulation fluid returns. During production in the Reference Program, the quantity of formation water produced will be taken as 3 bbl/MMCF of gas produced.

1.111
Most of the nongaseous wastes generated during the Reference Program fall into the category of "solid waste" as rather broadly defined in Section 1004 of the Resource Conservation and Recovery Act (RCRA).*

1.112
Many of the generated wastes could be classified as hazardous or special waste under the proposed RCRA regulations (40 CFR 250). Briefly, a waste is hazardous if it (1) exhibits certain characteristics, i.e., ignitability, corrosiveness, reactivity, or toxicity, as defined in §250.13, or (2) listed in §250.14 because of mutagenic, bioaccumulative, or toxic properties as characterized in §250.15.

1.113
The special waste** category was created by the USEPA because, although certain large-volume wastes are likely to be classified as hazardous according to the above-mentioned criteria, the USEPA had little information about the composition, characteristics, and the degree of hazard posed by these wastes, nor did the USEPA have data on the effectiveness or economic practicability of current or potential waste-management technologies. Gas and oil drilling muds and oil production brines (but not gas production brines) are all classed as special wastes, by definition, according to §250.46-6, provided that they are determined to be hazardous wastes as per the above criteria for that category (USEPA 1978).

1.114
In §250.13 the USEPA has proposed, as a test protocol for solid waste classification, subjecting the waste to a prescribed chemical extraction procedure with 0.5 N acetic acid solution. It is not known whether any natural gas

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*"The term 'solid waste' means any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under section 402 of the Federal Water Pollution Control Act, as amended (86 Stat. 880), or source, special nuclear, or byproduct materials as defined by the Atomic Energy Act of 1954, as amended (68 Stat. 923)." Note especially that a "solid waste" so defined may not in fact be solid.

**These are wastes which, when hazardous, the USEPA proposes to regulate with special standards; hence the term "special" waste.

development and production wastes have been subjected to the extraction procedure of §250.13. Also, this procedure is merely proposed and is subject to change if and when the final version of 40 CFR 250 is promulgated.

1.115
Because the basic ingredient of many water-based drilling fluids, bentonite clay, is commonly considered to be relatively chemically inert, it is often assumed that these water-based fluids are chemically very simple (McGregor et al. 1978). Although it is true that the bentonite clay itself will not likely prove hazardous in the RCRA sense by any reasonable testing protocol, the chemistry of clay minerals is anything but simple. In particular, clay ion exchange and sorption properties could provide the basis for classification of spent drilling fluids as hazardous when hazardous additives are used together with bentonite. The various additives which may have been adsorbed to or absorbed by the clay may desorb under the conditions of the RCRA test protocol. Thus, the properties of the additives are also of significance.

1.116
Because the composition of the drilling fluid varies and the chemical structure of the components, when identified, is often unavailable or inadequately characterized, it is not possible to make an a priori RCRA classification of drilling fluids in general. The classification of all spent drilling fluids as special waste because of presumed hazardous properties may in fact be regulatory overkill and may pose an unreasonable restraint on the industry if wastes from a land-based drilling program in similar formations using similar technology are not designated as hazardous or special wastes. Because the composition of the drilling fluids may vary considerably, depending on individual well characteristics, some kind of periodic monitoring of the drilling fluid waste stream from each drilling operation might be appropriate so that the fluid may be directed to the appropriate kind of waste-disposal treatment facility as its properties change during the course of the operation. As an alternative, the use of additives known to be hazardous could be strictly regulated; thus, most of the wastes would not contain these hazardous additives and would be suitable for less restrictive waste management schemes. The list of prescribed and restricted additives could be amended by addition or deletion as necessary. For the purpose of the waste management scheme considered below, all of the spent Reference Program drilling fluids will be considered as special waste in the RCRA sense.

1.117
Because the potentially noxious quality of cuttings is caused by adsorption of noxious additives or residuals onto the rock and fines, it is unlikely that rinsed cuttings would be classified as hazardous waste under the RCRA test protocol (unless the rock itself contained hazardous components). Consequently, Reference Program cuttings are classified as conventional wastes. It would still be prudent to require some kind of periodic monitoring of the cuttings during the course of drilling to verify their nonhazardous nature.

1.118
Two commercial guar-gum-based fracturing additives, fundamental to Reference Program development activities, contain silica and/or talc as well as guar gum; they have been found by bioassay to be nontoxic to 10,000 ppm in 24 hours (Borodczak 1968). The stimulation returns, i.e., the fluid which comes back to the surface after a well stimulation operation, are thus not likely to be

hazardous in the RCRA sense, unless as a result of particular drilling circumstances it might become necessary to add some of the much more toxic detergents or surfactants to the stimulation fluid.

1.119
Under the proposed RCRA criteria, the formation waters would not qualify as hazardous waste. However, the USEPA is considering use of the Water Quality Criteria under the Clean Water Act as a basis for setting test protocol solute levels, in addition to the USEPA National Interim Primary Drinking Water Standards (USEPA 1978). Under such circumstances, the total dissolved solids level in the formation water could conceivably exceed that level based on the Drinking Water Standards and thus the formation water could therefore be classified as a hazardous waste. Similarly, the acidizing returns, which contain a large percentage of formation waters, could also be classified as hazardous waste.

Waste Management Strategy

1.120
Some of the Reference Program wastes--i.e., drilling fluids, formation waters, deck drainage, completion fluid, spent acid, and stimulation returns--are considered to be hazardous or special wastes according to contemporary interpretation of RCRA regulations and will require special handling* onshore. Drilling and stimulation fluids comprise the largest portion of this volume of waste as may be seen from Table 1-29. Drill cuttings, excess cement, and domestic waste are classified as conventional wastes and can be handled through disposal in conventional landfills. Sanitary wastes would be treated in existing municipal waste-treatment plants. A schematic diagram of the suggested waste management strategy is presented in Figure 1-16.

1.121
The USEPA (1978) has prescribed design and operating standards in proposed RCRA regulations which are intended to minimize the escape of hazardous waste constituents to the environment. Depending on the geology and climate of the site location, limits are placed on the maximum permeability of the landfill liner material (1×10^{-7} cm/s) and the exact design and material of the liner. In addition, systems for the detection, collection, and removal of leachate may be required, particularly in nonarid climates. However, if the drilling and completion fluid waste stream is considered to be a special waste under §250.46-6 of the proposed regulations, the waste disposal facility is not subject to the groundwater and leachate monitoring requirements of §250.43-8.

1.122
The present availability of suitable landfills in the Reference Program Study Region is severely limited. A list of solid waste-disposal sites in Ohio, available from the Office of Land Pollution Control of the Ohio Environmental Protection Agency, contains little information beyond the name and location of the facility and the mailing address of the licensee; most of the facilities appear to be sanitary and municipal landfills; in any case, liquid sludges and

*Wastes requiring special handling are all shunted to the drilling and completion fluid waste stream.

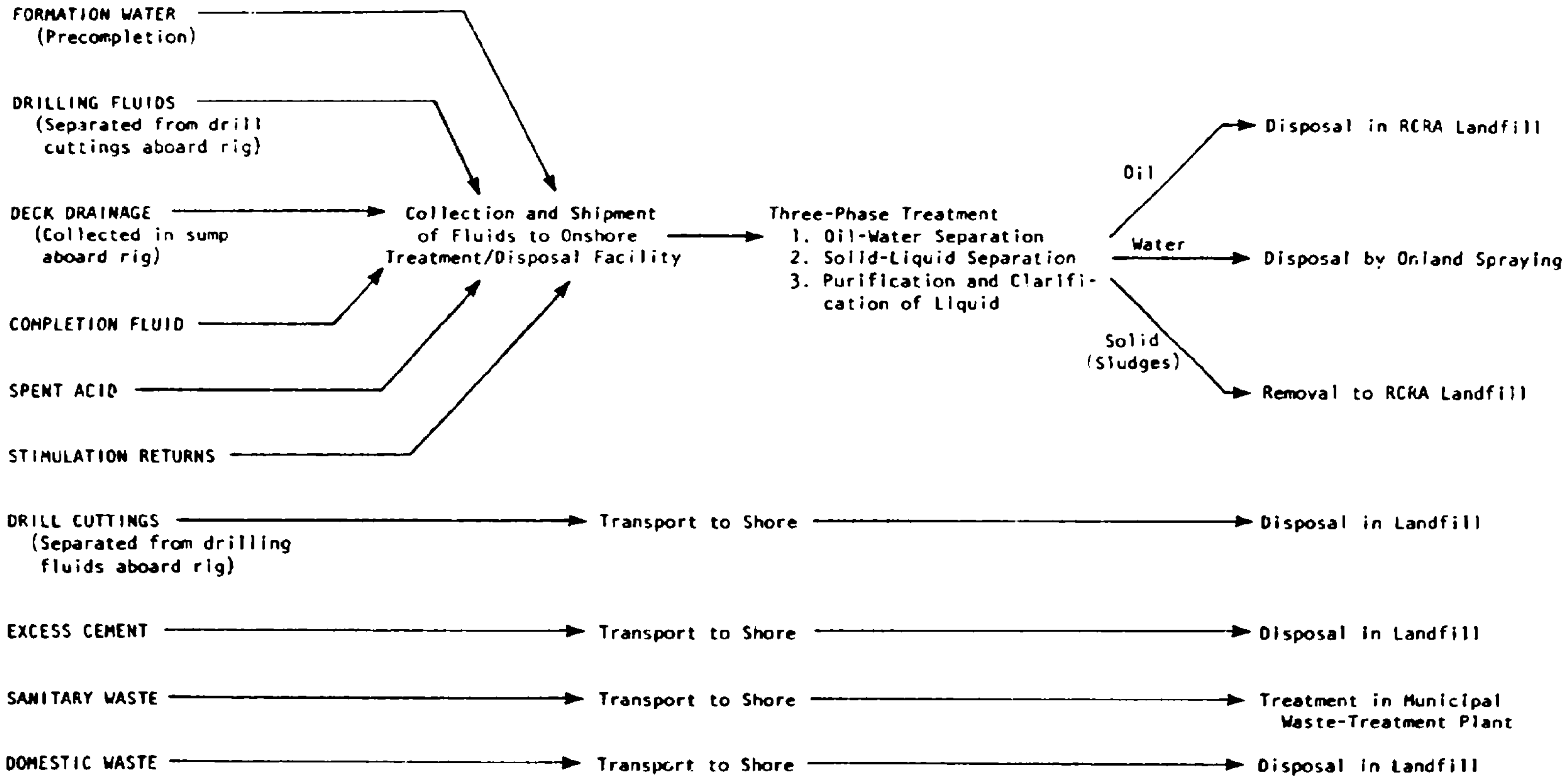

Figure 1-16. Waste Management Strategy for Materials Used and Residual Generated During Routine Reference Program Development Activities.

toxic materials are prohibited (Redman 1979--personal communication). According to a spokesman for the Bureau of Waste Disposal, New York State Department of Environmental Conservation (Mitrey 1979--personal communication), both drilling fluids and drill cuttings would fall within the state's hazardous wastes category (drill cuttings cleared of any contaminating oil and/or grease would not be so classified). Furthermore, there are only two state-licensed secure landfill facilities suitable for the burial of hazardous wastes in the vicinity of Lake Erie in New York State, both in Niagara County and both privately run. In Erie County, Pennsylvania, there is only one solid waste landfill with a permit for "normal, domestic-type waste", as well as several industrial disposal sites of an unspecified nature which are used exclusively by the companies that own them; however, the siting of landfills is reportedly not as much of a problem in the coal-mining country about 150 miles from the Lake (Crawford 1979--personal communication). The use of abandoned mine areas for disposal will require that operators filing for federal permits collect site-specific data--e.g., soil permeability, potential leachability of wastes, stability of disposal material. RCRA requirements must also be considered.

1.123
The quantities of waste produced by the entire Reference Program may be estimated from the quantities of wastes produced per well as given in Table 1-29 and from the leasing strategy given in Tables 1-18 and 1-19. The total quantities of particular categories of waste produced per lease area and per state in the Reference Program are presented in Table 1-31. Much of the drilling waste volume is water, which in principle may be separated from the solids, thus reducing the volume (by as much as 60% based on the drilling experience discussed below).

1.124
The drilling- and stimulation-fluid waste stream will be directed to an onshore lined or impermeable bottom holding facility (sump) where preliminary material separation takes place. Experience in treatment and disposal of waste fluids from onshore holding sumps in western Canada (Specken 1975) has been used to design the Reference Program waste-management scheme. The treatment process has three objectives: oil-water separation, solids-liquid separation, and extraction of environmentally objectionable components from the clarified water phase. Wastes in the sump must be sampled and analyzed to plan for effective treatment. First, the existence and approximate volume of liquid hydrocarbons and suspended solids must be ascertained. Then, samples must be taken to determine the proper sequence and dosages of chemicals required for successful toxicity reduction and clarification.

1.125
The treatment and subsequent disposal of wastes contained in the sump consists of five steps: oil removal, first clarification, water detoxification, final clarification, and pumpout. Any oil scum is skimmed from the surface of the aqueous fluid and disposed of in a RCRA landfill. Large volumes of oil are not expected in the Reference Program. Removal of some of the suspended solids from the aqueous fluid is accomplished prior to detoxification by dispersing coagulants and flocculants into the water; about 60% of the total fluid body can be converted to a solids-free water layer (Specken 1975). If the sump fluid is determined to be toxic through bioassay, it must be chemically treated to reduce the concentration of toxic components; the exact treatment chemicals required depends on the particular toxic components found.

Table 1-31. Quantities of Wastes Produced per Lease Area and State by the Reference Program

Lease Area	Rig Type[a]	Rig Years No.[b]	Rig Years Interval[c]	Producing Wells (no.)	Dry Holes (no.)	Wastes: Drilling Fluid (acre-ft)	Deck Drainage (acre-ft)	Completion Fluid (acre-ft)	Spent Acid (acre-ft)	Stimulation Fluid (acre-ft)	Drill Cuttings (acre-ft)	Excess Cement (acre-ft)	Sanitary Wastes (acre-ft)	Domestic Wastes (tons)
N.Y.														
I	Ja	3.4	6→8(9)	85	13	5.31	0.08	0.43	0.12	4.96	3.01	0.13	9.54	63.95
II	Ja	4.7	1→4(5)	116	19	7.31	0.11	0.58	0.17	6.79	4.15	0.17	13.12	88.57
III	FA	10.2	6→15(16)	204	41	13.36	0.24	1.03	0.29	11.90	6.41	0.48	29.33	188.70
Total				405	73	25.98	0.43	2.04	0.58	23.65	13.57	0.78	51.99	341.22
Pa.														
IV	FC	8.9	4→11(12)	142	62	12.38	0.23	0.27	0.25	8.28	7.03	0.38	29.12	188.03
V	Jb	11.4	1→11(12)	217	91	19.17	0.30	0.42	0.37	12.65	13.43	0.36	33.55	247.80
Total				359	153	31.55	0.53	0.69	0.62	20.93	20.46	0.74	62.67	435.83
Ohio														
VI	Ja	11.2	10→20(21)	190	100	19.25	0.30	0.20	0.35	11.08	14.23	0.33	37.32	255.68
VII	FC	11.7	13→23(24)	164	94	16.23	0.31	0.17	0.30	9.56	9.25	0.47	38.79	252.32
VIII	FB	13.0	13→25	182	104	17.99	0.34	0.19	0.34	10.61	10.26	0.52	43.01	279.71
IX	Jc,d	10.0	12→15(16)	169	90	17.20	0.27	0.17	0.31	9.85	12.71	0.29	33.32	228.32
X	Jb,e	8.0	13→16	136	72	13.81	0.21	0.14	0.25	7.93	10.20	0.24	26.76	183.37
XI	Je	8.9	4→11(12)	151	80	15.34	0.24	0.16	0.28	8.80	11.33	0.26	29.72	203.65
XII	FA	10.8	17→26(27)	151	86	14.91	0.29	0.16	0.28	8.80	8.50	0.43	35.64	231.79
XIII	FB	11.4	1→11(12)	268	25	18.81	0.36	0.28	0.50	14.99	10.72	0.59	44.96	294.56
XIV	Jc,d	17.8	{1→10(11) 4→10}	409	53	30.67	0.49	0.42	0.76	23.85	22.67	0.60	61.41	412.06
XV	Jc,d	4.6	27→28(29)	78	41	7.90	0.12	0.08	0.14	4.55	5.84	0.14	15.31	104.92
XVI	FB	6.8	28→33(34)	95	55	9.44	0.18	0.10	0.18	5.54	5.38	0.27	22.71	146.69
Total				1993	800	181.55	3.11	2.07	3.69	115.56	121.09	4.14	388.95	2593.07
TOTAL				2757	1026	239.08	4.07	4.80	4.89	160.14	155.12	5.66	503.61	3370.12

[a] J = jack-up rig (separate lower-case letter a through e for each rig); F = floater rig (separate upper-case letter A through C for each rig).

[b] Note that the number of rig years may exceed the years in the interval column when two rigs operate in a lease area.

[c] The numbers in parentheses indicate final years that are not complete years.

A final clarification by means of coagulation-flocculation is performed to remove any residual suspended solids. Another bioassay for toxicity is performed; if the water is found to be nontoxic, it is disposed of by pumping it onto adjacent land through an irrigation hose or sprinkler. The sludge at the bottom of the sump is then removed to a RCRA landfill. The sump may be reused for treatment of new wastes.

1.126
During the production phase of the Reference Program, 3 bbl of formation water will be produced with every million cubic feet (MMCF) of natural gas. This water will be brought to shore in underwater production lines and separated from the gas onshore. The amount of formation water produced per year in each state is given in Figure 1-17. Cumulative formation water production for lease areas and states is presented in Table 1-32.

1.127
Similar formation waters in Canada are frequently held in so-called "brine lagoons" pending a final decision on the ultimate disposition of these waters (Reeve-Newson 1979--personal communication). For example, it has been suggested that the salt from these waters could be used for road salting and other commercial applications. In the Reference Program, however, only subsurface injection of formation waters into suitable geologic strata will be considered.

1.128
As noted by Donaldson (1979), aqueous fluids scheduled for injection into subsurface strata must be free of suspended solids, oil, and gas. The solids create a restriction to flow at the face of the formation, commonly called the "skin effect," and the oil and gas decrease the permeability to the aqueous phase by competing for the flow channels. Therefore, the objective of preinjection treatment of wastes is to remove solids, oil, and gas, or to stabilize a waste that may have a tendency to form a second phase during injection.

1.129
Unless formation brines are processed in a closed system, chemical reactions with air may result in the precipitation of various salts and hydroxides. Therefore, aeration equipment is used to complete the precipitation, which is followed by sedimentation and filtration in order to clarify the liquid. To prevent the restriction of flow resulting from the accumulation of scale deposits in pipes and at the face of the formation, chemicals such as phosphates may be added to the brine. Corrosion-inhibiting chemicals may also be added because brines containing dissolved oxygen are very corrosive to ferrous metals.

1.130
A subsurface-disposal system can be successful only if a porous, permeable formation of wide areal extent is available at sufficient depth to ensure safety for storage and retention of the injected fluids. The stratum must be below all freshwater aquifers and confined vertically by rocks that, for practical purposes, are impermeable to waste liquids. In addition to the protection of usable water resources, the vertical confinement of liquid wastes also protects any developed or undeveloped hydrocarbon and mineral deposits (Donaldson 1979).

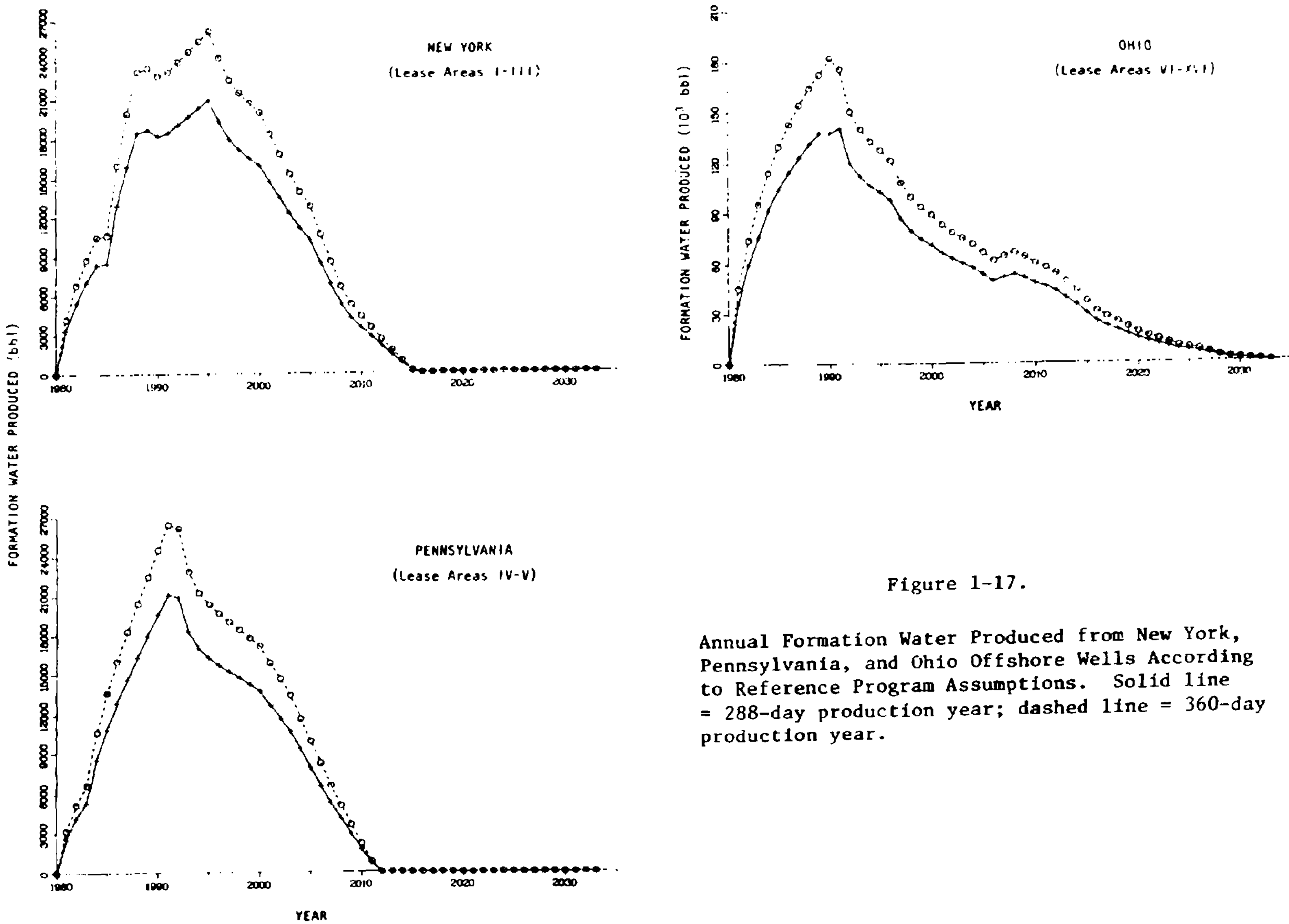

Figure 1-17.

Annual Formation Water Produced from New York, Pennsylvania, and Ohio Offshore Wells According to Reference Program Assumptions. Solid line = 288-day production year; dashed line = 360-day production year.

Table 1-32. Total Formation Water Produced per Lease Area and State[a]

Lease Area	Production Interval	288 days Total Gas Volume (BCF)	288 days Formation Water (10^3 bbl)	360 days Total Gas Volume (BCF)	360 days Formation Water (10^3 bbl)
N.Y.					
I	7→29	28	84	35	100
II	2→25	38	110	48	140
III	7→36	67	200	84	250
Total		133	394	167	490
Pa.					
IV	5→32	47	140	58	180
V	2→32	71	210	89	270
Total		118	350	147	450
Ohio					
VI	11→41	63	190	78	230
VII	14→44	54	160	67	200
VIII	14→45	60	180	75	220
IX	13→36	56	170	70	210
X	14→36	45	130	56	170
XI	5→32	50	150	62	190
XII	18→47	50	150	62	190
XIII	2→27	210	640	270	800
XIV	2→26	330	980	410	1200
XV	28→49	26	77	32	96
XVI	29→54	31	94	39	120
Total		975	2921	1221	3626
TOTAL		1226	3665	1535	4566

[a] In the Reference Program, 3 bbl of formation water will be produced with every MMCF of natural gas (1 bbl = 42 gal = 1.289×10^{-4} acre-ft).

1.131
The most common lithologies used for disposal formations are sandstones, conglomerates, limestones, and dolomites. The thicknesses and potential suitability of various formations for liquid waste injection in the vicinity of Lake Erie are identified in Table 1-33. Some of the formations that appear to be suitable may have to be rejected because they are freshwater aquifers.

Construction Activities

1.132
Various kinds of facilities will have to be either acquired or constructed by operators in the course of developing Lake Erie natural gas. Some facilities will be directly responsible for transmitting or processing gas or treating

Table 1-33. Suitability of Geological Formations in the Lake Erie Vicinity for Injection of Gas Well Wastes[a]

System	Formation	Lithology	Maximum Thickness (m)[b]	Suitability for Injection
Mississippian	Berea[M,O]	Sandstone	?	Good
Devonian	Upper Devonian[M,O,P,N]	Shale	390[O,P,N]	
Devonian	Onondaga[P,N,O] Bois Blanc[M]	Chert, dolomite Limestone	46[N] 91[M]	Depends upon permeability
Devonian	Oriskany[P] Springvale[O]	Sandstone	21[O]	Good if sufficient extent, thickness, and permeability
Devonian	Holderberg[N,P]	Limestone	9	Depends upon permeability and extent
Silurian	Cayugan[M,N,O,P]	Halite, anhydrite, shale, dolomite	121-210[O]	Confining bed
Silurian	Lockport[O,P]	Dolomite	106[O,P]	Limestone barrier reefs are gas reservoirs
	Niagra[M,N] Clinton[P,N]	Dolomite-shale		Depends upon extent and permeability
	Newberg[O]	Dolomite	Thin	Porous saline, good if large enough
Silurian	Rochester[M,O,P,N]	Shale and minor dolomite	4[M]-30[P]	Confining bed
Silurian	Packer Shell[O]	Limestone, dolomite	3-9	Poor, too thin
	Reynales-Irondequoit[P,N]			
Silurian	Medina[O,P,N]-Whirlpool	Sandstone	Combined total-15	Good, sandstones
Clinton[O,P]	Cabot Head	Shale and sandstone		Carbonates, depends upon extent and permeability
Clinton[O,P]	Grimsby	Sandstone and shale		
Clinton[O,P]	Thorold	Sandstone		
Clinton[O,P]	Manitoulin[O]	Limestone-dolomite		
	Brassfield[O]	Limestone-dolomite		
	Niagra-Clinton[M]	Dolomite-shale		
Ordovician	Queenston[N,P,O] (Juniata)	Shale	30[O]-240[N]	Confining layer
	Cincinnatian	Shale	300-550	Confining layer
Ordovician	Trenton[M,O,P,N]	Limestone, dolomite	30[M]-150[P]	Depends upon permeability
Ordovician	Black River	Limestone, dolomite	84-155	Depends upon permeability
Ordovician	Glenwood	Argillaceous dolomite	0-8	Poor
	Shadow Lake	Dolomite, sandstone		
Cambrian	Upper Cambrian	Dolomite, sandstone	?	Good if of sufficient extent; good secondary porosity
Cambrian	Kerbel[O]	Sandstone	15-30[O]	Good
Cambrian	Mt. Simon[M,O] Potsdam[P,N]	Sandstone	38	Good

[a]Based on data from Briggs (1968), Clifford (1973), Hardaway (1968), and McCann et al. (1968).

[b]To convert m to ft, multiply by 3.2808.

M = Michigan, O = Ohio, P = Pennsylvania, N = New York.

and storing program wastes; others will house management personnel onshore and provide storage space for program inventory. In all cases, impacts caused by construction activities are of a different nature and duration than impacts caused by routine activities and potential hazards and accidents. An overview of Reference Program construction activities with potential environmental consequences is presented in Table 1-34.

1.133
Until a lease area is proven to be commercially productive, an operator will be hesitant to commit capital to construction of new onshore facilities. Consequently, during initial exploration activities, harbor space, storage warehouses, and office buildings will be rented wherever available and convenient. In the absence of suitable RCRA-approved landfills in the Reference Program Study Region, each operator involved in exploratory drilling would be obligated to construct waste treatment/disposal facilities, i.e., fluid sumps, spray irrigation hardware, and injection wells to handle special and hazardous wastes generated during exploratory drilling.

1.134
It is assumed that developmental drilling is initiated during the first year of the Reference Program (1980); each operator involved in the program at this point would have an immediate need to acquire permanent offices, harbor space, and storage/staging facilities. Where these facilities already exist, they may be leased or rented. In some cases, new facilities must be constructed or existing facilities modified to suit Reference Program needs. Additional waste-treatment/disposal facilities will also be required to handle increased development activity wastes. New construction of shoreline facilities and/or structures would probably require Corps permits; thus site-specific consideration would be given to these activities and their effects. The USEPA would review all applications for Corps permits. For a summary of facilities required, locational constraints, and sources of potential impacts, see Table 1-34. Impacts are discussed in Chapter Four - Water Quality (Table 4.3); Water Use, Impacts to Ports, Shipping, and Navigation; and Socioeconomics, Employment.

1.135
Every operator will want to produce gas from completed wells as quickly as possible to offset substantial capital outlays incurred during exploration and development. Since production wells will be completed during the first year of the Reference Program, underwater pipelines and onshore gas process/treatment facilities must be constructed concurrently with developmental drilling. As soon as 25 wells are established in a lease area, plans can be made for siting a gas process/treatment facility and routing pipelines between the field and landfall. Pipeline construction begins by welding 6- or 8-in. diameter flowline sections into a 0.5-mile pipe onshore; these flowlines are then towed to location by a tug. Pipes located within the 30-ft water depth contour are buried in a trench to a depth of between 5 and 10 ft for protection against ice scour and anchor snags. Pipes in water depths greater than 30 ft are laid on the lakebed. Where sediments are consolidated, the pipe can be screw-anchored; in soft sediments the pipe will sink into the unconsolidated mud. A trunk line and gathering lines are also towed to each field location and sunk in place (see Appendix B, Table B.5). Sections of pipe are connected on location through underwater welding by divers or by lifting pipe sections and welding on a pipe barge. Divers connect wellheads to the underwater pipeline system as soon as they are completed. In the Reference Program, fields are scheduled to come online one year after they are drilled.

Table 1-34. Reference Program Construction Activities with Potential Environmental Consequences

Activity	Facility Required and Method of Acquisition	Locational Constraints	Source of Potential Impact
1. EXPLORATION			
1.1 Seismic Survey[a]	Temporary Headquarters: Rental of existing offices to manage survey cruise	Offices will ideally be located as close as possible to a major Lake Erie port	Not applicable when existing facilities are used
	Harbor Space for Survey Vessel: Rental of berths in existing harbors along vessel's survey route	Lake Erie ports with harbor facilities to accommodate survey vessel will be required	Not applicable when existing facilities are used
1.2 Basement Test Wells	Temporary Headquarters: Rental of existing building to house onshore management personnel	Building will ideally be located as close as possible to a major Lake Erie port	Not applicable when existing facilities are used
	Temporary Storage Yard: Rental of existing warehouse or land for equipment storage and transfer	Must be located dockside at a Lake Erie port able to accommodate service vessels	Not applicable when existing facilities are used
	Harbor Facilities: Rental of existing berths for service vessels	Must be located at a Lake Erie port able to accommodate service vessels	Not applicable when existing facilities are used
	Operator Waste Treatment/ Disposal Facility: New waste disposal facilities must be constructed for wastes designated as special or hazardous when existing waste disposal sites are unavailable and/or unsuitable	Waste disposal facility will ideally be located as close as possible to a permanent operator storage/staging facility to minimize transportation costs	Temporary impacts from noise, erosion, fugitive dust, traffic congestion, and esthetic disruption will occur; a small local work force will be sufficient for facility construction
		Location of each new facility will be subjected to careful site suitability analysis in accordance with federal, state, and local land-use and environmental laws, standards, and policies	A short-term land-use status change will occur on the land dedicated to the facility. Whether that land will eventually be able to be converted to other uses will depend on the properties of the wastes accepted and the effectiveness of facility design; if designed and operated properly, no wastes should be released from the facility to the environment
2. DEVELOPMENT (Leasing, Drilling, Well Completion, Well Stimulation)	Permanent Operator Headquarters: Purchase or lease of existing building	Building will ideally be located as close as possible (dockside) to a Lake Erie port able to accommodate drilling rigs and vessels	If a new building is constructed, temporary impacts from noise, erosion, fugitive dust, traffic congestion, and esthetic disruption will occur; a small, local work force will be sufficient for building construction

Table 1-34. Continued

Activity	Facility Required and Method of Acquisition	Locational Constraints	Source of Potential Impact
2. DEVELOPMENT (cont'd)	Permanent Operator Harbor Facilities: Purchase or rental of existing berths	Restricted to Lake Erie ports able to accommodate rigs and vessels that are located in close proximity to operator's lease area	Not applicable when existing facilities are used
	Construction of new berths or modification of existing berths		Suspension of lake sediments, elimination of some benthic organism habitat, and generation of fill material from dredging
	Permanent Operator Storage/Staging Facility: Purchase or rental of existing warehouse and storage yard	Warehouse will ideally be located as close as possible (dockside) to a Lake Erie port able to accommodate drilling rigs and vessels to facilitate material loading and offloading; if possible, warehouse and headquarters will be at same location	
	Construction of new warehouse		If a new warehouse is constructed, temporary impacts from noise, erosion, fugitive dust, traffic congestion, and esthetic disruption will occur; a small local work force will be sufficient for warehouse construction
	Permanent Operator Waste Treatment/Disposal Facility: New waste disposal facilities must be constructed for wastes designated as special or hazardous when existing waste disposal sites are unavailable and/or unsuitable	Waste disposal facility will ideally be located as close as possible to a permanent operator storage/staging facility to minimize transportation costs	Temporary impacts from noise, erosion, fugitive dust, traffic congestion, and esthetic disruption will occur; a small local work force will be sufficient for facility construction
		Location of each new facility will be subjected to careful site suitability analysis in accordance with federal, state, and local land-use and environmental laws, standards, and policies	A short-term land-use status change will occur on the land dedicated to the facility. Whether that land will eventually be able to be converted to other uses will depend on the properties of the wastes accepted and the effectiveness of facility design; if designed and operated properly, no wastes should be released from the facility to the environment
3. PRODUCTION			
3.1 Management of Production Activities	Operator Production Headquarters: Space can be shared in operator development headquarters	Production offices should be as close as possible to pipeline storage/staging facility	Not applicable when existing facilities are used
3.2 Pipeline Construction	Harbor Facilities: Space can be shared in harbor facilities dedicated to development activities if they are planned to accommodate pipe-laying activities	Must be located at a Lake Erie port able to accommodate service vessels and pipe-laying barges	If new berths must be constructed or existing berths modified, suspension of lake sediments and generation of fill material will result from dredging

Table 1-34. Continued

Activity	Facility Required and Method of Acquisition	Locational Constraints	Source of Potential Impact
3.2 Pipeline Construction (cont'd)	Pipeline Storage/Staging Facility: Space can be shared in facilities dedicated to development activities if they are planned to accommodate pipe-laying activities	Warehouse and/or storage yard will ideally be located as close as possible (dockside) to a Lake Erie port able to accommodate service vessels and pipe-laying barges to facilitate material loading and offloading	If a new warehouse and/or storage yard is constructed, temporary impacts from noise, fugitive dust, traffic congestion and esthetic disruption will occur; a small local work force will be sufficient for facility construction
	Underwater Natural Gas Pipelines and Glycol Injection Lines: Gas gathering, trunk, and flowlines must be assembled onshore and towed out into the Lake where they are laid All pipes in water less than 30 ft will be buried to a depth of between 5 and 10 ft. Actual depth required and distance offshore to which burial occurs depends on site-specific factors; however, in most cases the 30-ft contour may be an appropriate distance All other pipes will be laid in sediments and screw-anchored if possible Glycol dispensing, trunk, and feeder lines will be bundled to and installed with gas lines	All underwater gas flowlines and glycol feeder lines will follow the shortest distance between a trunk line and a designated landfall. The following areas should be avoided in pipeline routing: steep slopes, anchorage areas, existing underwater objects, any active faults, rock outcrops, and environmentally sensitive areas	Pipeline laying and burial will cause suspension of lake sediments and eliminate bottom strata supporting existing benthic organisms; a work force of approximately 25 welders, pipefitters, divers, and barge operators will be employed by each operator to construct underwater pipelines, landfalls, and onshore pipelines
	Pipeline Landfall: Each field of 25 wells will have a flowline coming to shore at a landfall; the landfall will be constructed to ensure protection of the pipeines and land that they traverse	Landfalls will be sited in convenient locations between flowlines and shore facilities that do not constrain engineering design or threaten environmental damage; high erodable bluffs, densely populated urban areas, productive stream beds, wetlands, and recreational areas should be avoided	Temporary impacts from noise, erosion, fugitive dust, and esthetic disruption will occur while the landfall is under construction; applications of herbicides to maintain access to pipeline right-of-way could introduce pollutants to lake water

Table 1-34. Continued

Activity	Facility Required and Method of Acquisition	Locational Constraints	Source of Potential Impact
3.2 Pipeline Construction (cont'd)	Underground Gas and Glycol Pipelines: A gas flowline and glycol feeder line will be buried onshore for approximately 0.5 mile between a landfall and shore gas facility	Underground pipelines will follow the shortest path between the two end points while avoiding obstructions and environmentally sensitive areas	Temporary impacts from noise, erosion, fugitive dust, traffic congestion, and esthetic disruption will occur while pipeline corridor is under construction; maintenance of pipeline corridor through mowing and/or applications of herbicides could introduce pollutants into nearby surface or subsurface waters
	Underground Gas Pipeline: Gas leaving the shore facility will travel approximately 0.5 mile to the nearest distribution/transmission line; the pipeline will be buried	Underground pipelines will follow the shortest distance between the two end points while avoiding obstructions and environmentally sensitive areas	Temporary impacts from noise, erosion, fugitive dust, traffic congestion, and esthetic disruption will occur while the pipeline corridor is under construction; maintenance of pipeline corridor through applications of herbicides could introduce pollutants into nearby surface or subsurface waters
3.3 Gas Process and Treatment Plant Construction	Gas Process or Treatment Facilities: Construction of buildings, storage areas, and parking lots on 3-10 acre sites Construction of approximately 0.5 mile of service road to gain access to each plant constructed	The location of each new facility will be subjected to careful site suitability analysis in accordance with federal, state, and local land-use and environmental laws, standards, and policies; facilities should be sited away from densely populated areas to avoid subjecting humans to any excessive noise or smell, or to explosion risk	Temporary impacts from noise, erosion, fugitive dust, traffic congestion, and esthetic disruption will occur; a small local work force of approximately 20 men will be sufficient for facility construction
4. DECOMMISSIONING	Storage/Staging Facility: Space can be shared in facilities dedicated to development activities	Warehouse and/or storage yard will ideally be located as close as possible (dockside) to a Lake Erie port able to accommodate rigs and vessels	Not applicable when existing facilities are used

[a]Has already been completed in U.S. waters of Lake Erie.

1.136
A wing valve is connected between the wellhead and gathering line so that individual wells can be added or deleted from field production. Each well is also serviced by a backflow check valve to prevent high field pressures from damaging the reservoir of a lower-pressure well (the well is shut-in and isolated from the rest of the field if its pressure is significantly lower than average field pressure). A pressure-drop-actuated safety valve is connected at the junction of each trunk and flowline to shut in the entire field in the event of a line break.

1.137
After choosing a landfall location that is convenient to all lease area fields and not constrained by environmental conditions or engineering design considerations (e.g., slope, soil stability, erosion hazard), a pipe manifold system is constructed to connect flowlines into one onshore pipe run to the process/treatment plant. The onshore pipe is buried below frostline; the distance between landfall and process/treatment plant is approximately 0.5 mile in the Reference Program.

1.138
Onshore process and treatment facilities are constructed on 3 to 10 acre sites in time to accept gas from offshore wells as soon as pipelines and landfalls are completed. Each facility is accessed onshore through a 0.5-mile service road built simultaneously with the plant. Although the gas plant structure is constructed at the beginning of the contributing lease area's production life, process and treatment components (i.e., compressors, dehydrators, glycol injection units, methyl ethyl amine [MEA] units, Claus sulfur recovery units, and Shell-Claus offgas treaters [see Appendix B, Tables B.6 and B.7]) are added in stages to correspond with increased lease area production with annual additions of fields.

1.139
The production and collection cycle is completed by constructing a pipeline from the process/treatment plant to the nearest distribution/transmission line. This line is also buried below frostline and will be approximately 0.5 mile long.

Hazards and Accidents with Potential Environmental Consequences

Nature and Timing of Events

1.140
During exploratory and developmental drilling, a number of special events (Table 1-35) can be anticipated with a frequency high enough to almost be considered routine. If handled properly by the operator, these hazards will provide little opportunity for uncontrolled release of contaminants to the environment.

1.141
Drilling fluid additives will be injected into the wellbore in the event that shales begin to agglomerate (balling shales) and impede proper drill bit mechanics; additives will also be used in the event that drill pipe or collars bind in the wellbore or drilling fluids are lost at abnormal rates to formations

Table 1-35. Hazards and Accidents with Potential Environmental Consequences in the Reference Program

Nature of Hazard and/or Accident	Source of Potential Impact	Fate of Residuals Generated and Materials Used
	HIGHEST FREQUENCY	
Exploration and Development		
Balling shales	Addition of dispersants or deflocculants (e.g., spersene, chrome lignosulfonate, caustic soda, calcium lignosulfonate, tannins, lignins, phosphates) to drilling fluids to break up shale lumps	Additives remain in drilling fluid and will ultimately be disposed of onshore with spent fluids
Stuck drill pipe or collars	Addition of lubricants or solvents (e.g., diesel fuel, Pipe Lax, Black Magic, Pipe Free, Scot Free, Petrocote) to wellbore to reduce friction on pipe	Additives may either be selectively recovered and saved or brought to shore for disposal with spent fluids
Gas zone encountered while drilling	Switch in drilling fluid from $CaCl_2$ to polybrine mud. Any gas that might be encountered is separated from the drilling fluid on the rig and vented or flared to the atmosphere	Both $CaCl_2$ and polybrine fluids can be saved aboard and used again until necessary fluid properties are lost; fluids are then disposed of onshore
Wellbore fluids lost to a formation	Addition of "lost circulation" controlling material (e.g., walnut hulls, sawdust, chopped cellophane, straw, chopped inner tubes, ground mica, cottonseed hulls, shredded wood fiber, shredded cellulose)	Most of the additive will remain in the formation; any fraction of the additive returning to the surface will be removed from the drilling fluid by the solids control system
Accidental release of small amounts of material to the Lake through bad housekeeping practices	Small amounts of trash, garbage, human wastes, and/or refined machine lubricants may be blown, dumped, or spilled overboard	Materials will either disperse in water and sink to the bottom of the Lake or float on its surface and be washed ashore
Small volume-high pressure gas pocket encountered (most likely experienced in Devonian shales)	If, for example, a pressurized pocket of 100 ft^3 of gas is encountered, gas will flow at 3.7 MCF per day for 2 days under the following conditions: Depth = 1000 ft Reservoir pressure = 1000 psia Reservoir temperature = 100°F Specific gravity of gas = 0.65 Compressibility constant (Z) = 0.859	Hydril is closed and gas is circulated up the wellbore through a gas/mud separater and vented or flared to the atmosphere
	MODERATE FREQUENCY	
Exploration and Development		
Deck drains split open and/or leak	Drilling fluids spilled around the rotary table and lubricants dripping from machinery will be free to leak into the Lake	Up to 40 gal of drilling fluids and small amounts of oily wastes (machine lubricants) will be released to the Lake for one day until drain is repaired

Table 1-35. Continued

Nature of Hazard and/or Accident	Source of Potential Impact	Fate of Residuals Generated and Materials Used
Spillage, leakage, or dumping of materials during offloading and loading	During material transfer, cables may break on derricks, lines may break when loading or offloading liquids, or bulk loads may be lost during bad weather	Varying amounts of the following materials may be dumped into the Lake and sink, or disperse and/or dissolve if containers are ruptured: 15-20 hundred-pound sacks of cement, bentonite, $CaCl_2$, KCl, polybrine, Ceastop, Mixical 1-2 hundred-pound sacks of NaOH or chrome lignosulfonate One 55-gal drum of bactericide, oxygen scavenger, amine-coat chemicals, or magconol 200-300 gal of human wastes transferred from holding tank 200-400 lb of trash and garbage transferred in containers
Production		
Rupture of 8-in. gas flowline and glycol feeder	Large anchors or ice scour could sever flowlines, resulting in releases of gas, formation water, H_2S, and small amounts of liquid hydrocarbons to the Lake; because glycol line is bundled with gas line, it too would be ruptured and glycol would be released to the Lake	Under worst-case accident assumptions, the following are postulated: Release of 23.75 MMCF/day at point of rupture for 3 days; some of this gas will dissolve in the water, but most will bubble to surface Release of formation water at a rate of 5 bbl/MMCF (118.75 bbl/day for a field of 25 wells) Release of small amounts of liquid hydrocarbons at a rate of 0.16 bbl/MMCF (3.8 bbl/day) Release of glycol at a rate of 2.7 bbl/h for 1 day (64.8 bbl) Release of 11,700 lb/day (for a field of 25 wells) of H_2S at a rate of 0.49×10^{-3} lb H_2S/ft^3 of gas released
	LOW FREQUENCY	
Exploration and Development		
Line or casing rupture	Kelly hose (mud line), mud pump, or discharge lines burst under high pressure during drilling	Mud pump will run for 2 min before being shut down, releasing 1200 gal of drilling fluid (e.g., polybrine and additives) to the Lake at a rate of 600 gpm
	Cement head splits under high pressure while cementing	Cement pump will run for 1 min before being shut down, releasing 126 gal of cement at a rate of 126 gpm
	Injection line bursts under high pressure or tubing bursts at wellhead during stimulation	Stimulation fluid pump will run for 1 min before being shut down, releasing 2310 gal of stimulation fluid at a rate of 2310 gpm
	Stimulation return line is cut by sand during collection of returns	If return line is severed at the beginning of collection process, up to 19,000 gal of stimulation fluid, 475 MCF of natural gas, 233 lb of H_2S, and 58 bbl of formation water will be released to the Lake before the well can be shut in

Table 1-35. Continued

Nature of Hazard and/or Accident	Source of Potential Impact	Fate of Residuals Generated and Materials Used
Line or casing rupture (cont'd)	Suction line on mud tank between valve and tank breaks during drilling	An entire liquid batch of drilling fluid (e.g., 11,340 gal of polybrine and additives) will be released to the Lake
	Production tubing and/or production casing breaks at total depth	Any completion fluid (up to 100 bbl) or HCl (up to 165 gal) could be lost to the formation opposite the break if that formation communicating with the casing is permeable; if not permeable, fluids would remain in wellbore until salvaged or migrate down outside of casing if wellbore extends deeper and cement around casing is inadequate
	Riser pipe splits at mud line during drilling	Mud pump will run for 2 min at a rate of 300 gpm before being shut down, releasing drilling fluid to the Lake (e.g., 600 gal during 2 min plus 840 gal in a 90-ft riser pipe = 1440 gal)
Failure of mud pit volume monitor	During a gas kick, drilling fluid could rise in mud pits and overflow before hydril is closed	Up to 200 gal of drilling fluid (e.g., polybrine, mud, and additives) will be released to the Lake
Wellhead is broken off	Large anchors dropped during bad weather, ice scour, or fishing nets could snag and break off wellheads not protected by caissons	Under worst-case assumptions, the following are postulated: Release of 950 MCF/day at wellhead for 5 days; some of this gas will dissolve in the water but most will bubble to the surface Release of formation water at a rate of 0.16 bbl/MMCF (0.152 bbl/day) Release of gl[illegible] at a rate of 0.108 bbl/[illegible].5 bbl/day) for 5 days Release of 4[illegible] lb/day of H_2S at a rate of 0.49×10^{-3} lb H_2S/ft^3 of gas released
	LOWEST FREQUENCY	
Exploration and Development		
Capsize of rig[a]	Bad weather during towing, collisions, or problems during rigging up could result in rig capsize	Entire rig inventory could be released to the Lake. Some materials could remain in containers and sink to the lake bottom; ruptured containers could result in materials dispersing and/or dissolving in the Lake
Capsize of service vessel	Bad weather in transit or collision could result in vessel capsize	Entire rig inventory could be released to the Lake. Some materials could remain in containers and sink to the lake bottom; ruptured containers could result in materials dispersing and/or dissolving in the Lake

Table 1-35. Continued

Nature of Hazard and/or Accident	Source of Potential Impact	Fate of Residuals Generated and Materials Used
Capsize of stimulation barge[a]	Bad weather in transit or collision could result in barge capsize	Entire rig inventory could be released to the Lake. Some materials could remain in containers and sink to the lake bottom; ruptured containers could result in materials dispersing and/or dissolving in the Lake
Gas kick with blowout (conducted up wellbore)	Large drilling fluid losses occur to formation while drilling into Clinton-Medina; Lockport pressure exceeds mud column pressure, and gases and liquids migrate up wellbore; failure in blowout prevention (BOP) equipment results in release of gas and liquids to environment	Under worst-case assumptions, the following are postulated: Release of 7100 gal drilling fluids to the Lake if all drilling fluids are forced out of a 2700-ft wellbore Venting to the atmosphere of 950 MSCF gas/day during the 15 days required to drill a relief well Release of 470 lb/day of H_2S at a rate of 0.49×10^{-3} lb H_2S/ft^3 of gas released Release of formation water at a rate of 5 bbl/MMCF (4.75 bbl/day) Release of liquid hydrocarbons at a rate of 0.16 bbl/MMCF (3.8 bbl/day)
Gas kick with blowout (not conducted up wellbore)[a]	If the blowout is not conducted up the wellbore but around the bottom of the surface casing or drive pipe, gas velocities could be sufficient to erode supporting sediments around jack-up legs	Same as above, except gas and liquids will be released to the Lake at the mud line If sediment erosion causes rig capsize, the entire rig inventory will be lost to the Lake
Explosion and fire at gas processing/treatment plant	Nonroutine leakage of small amounts of gases could accumulate in a closed building and be ignited by a spark; a small explosion in a strategic location could rupture a valve or high-pressure line, causing an even larger explosion accompanied by fire	Under worst-case assumptions, the following are postulated: Total destruction of the plant and loss of life to all workers in the plant Release and combustion of 23.75 MMCF/day of sour gas for one day until all vanished Release of 11,700 lb of H_2S (most of which will be oxidized to sulfur oxides) Release of small amounts of liquid hydrocarbons (3.8 bbl at a rate of 0.16 bbl/MMCF) which will be completely combusted Release of formation water at a rate of 5 bbl/MMCF to the plant (119 bbl)

Table 1-35. Continued

Nature of Hazard and/or Accident	Source of Potential Impact	Fate of Residuals Generated and Materials Used
	SPECIAL CATEGORY[b]	
Exploration		
Oil blowout conducted up wellbore[a]	While drilling a basement test well, a geopressurized oil zone is encountered in Cambrian rocks; formation pressure exceeds fluid column pressure, and gas and liquid migrate up wellbore; failure in BOP equipment results in the release of gas and liquids to the environment	Under worst-case conditions, the following are postulated: Release of 12,000 gal drilling fluids to the Lake if all drilling fluids are forced out of a 4600-ft wellbore Release of oil to the Lake at a rate of 20 bbl/day during the 15 days required to drill a relief well Venting to the atmosphere of 300 MCF gas at a gas/oil ratio of 1000 ft^3 gas to 1 bbl oil Release of formation water at a rate of 1 bbl water to 1 bbl oil (20 bbl/day)
Oil blowout around surface casing or drive pipe[a]	If the blowout is not conducted up the wellbore but around the bottom of the surface casing or drive pipe, gas velocities could be sufficient to erode supporting sediments around jack-up legs	Same as above, except gas and liquids will be released to the Lake at the mud line If sediment erosion causes rig capsize, the entire rig inventory will be lost to the Lake

[a]See Appendix C for details of worst-case accident assumptions used in modeling analysis.

[b]Described to demonstrate the effects of the most disastrous single event that could be imagined, although the possibility of the event is nearly zero.

(see Table 1-35). Special drilling fluids will be employed if gas is encountered while drilling. These fluids will protect the gas-bearing formation from damage for future production and provide an added measure of control against uncontrollable gas kicks. Frequently, when the drill bit passes through Devonian shales, small volume-high pressure pockets of gas will be encountered and must be vented before drilling can proceed.

1.142
In addition to anticipated hazards, accidents could occur over the lifetime of the Reference Program. Since no suitable empirical data are available from previous or existing offshore freshwater natural gas development programs, absolute frequencies of accident categories will not be predicted. The Reference Program was reviewed and analyzed for activities susceptible to accidents based on worldwide offshore petroleum development experience. The range of accident types was organized according to relative frequencies, i.e., one category compared against all others under Reference Program conditions (see Table 1-35).

1.143
Frequently during exploratory and developmental drilling, small amounts of materials and/or residuals may be released to the Lake through bad housekeeping practices. Less frequently, materials used in the drilling process may be released to the Lake during loading or offloading or as a result of deck drain leakage; also, pressurized lines, pipes, or casing may rupture and mud tanks

could overflow. There is some possibility that any rig or vessel used in the Reference Program could capsize while on location or in transit. An uncontrolled gas kick (blowout)--lowest frequency category (Table 1-35)--could even contribute to the capsize of a jack-up rig.

1.144
Although the conditions for an oil blowout (e.g., geopressurized reservoirs, high liquid hydrocarbon pore space saturation, high porosity and permeability) are not thought to exist in the Reference Program Study Region, a Special Accident Category was defined to hypothesize the effects of encountering an uncontrollable oil reservoir while drilling into Ordovician or Cambrian rocks.

1.145
During the production phase of the Reference Program, natural gas, hydrogen sulfide, formation water, small amounts of lightweight liquid hydrocarbons, and glycol may be released to the environment from pipeline and wellhead leaks or breaks, and from leaks and/or explosions at gas process/treatment facilities.

1.146
The quantities of residuals and materials released to the environment are described for each accident in Table 1-35. For a discussion of potential impacts resulting from these releases, see Chapter Four - Water Quality.

Fate of Residuals Generated and Materials Used

1.147
Additives used in the wellbore to mitigate downhole hazards can be selectively recovered and either stored for reuse or sent to shore for treatment and disposal. Generally, materials used aboard rigs and vessels will be containerized. Containers would have to be ruptured to release liquids and/or solids--e.g., diesel fuel, packaged drilled fluid components, additives, sewage wastes, and garbage--into the Lake. Large quantities of drilling fluids would be released in bulk during rig capsize. Drilling fluids, produced formation water, lightweight liquid hydrocarbons, and gases would be continuously released from a well blowout until the well was brought under control. A valving system has been designed into Reference Program pipelines to selectively shut-in wells or fields after detecting significant pressure drops upon wellhead or line breaks. Gases and liquids will be released until valves are actuated. Since glycol lines are bundled together with gas lines, a gas line break would result in release of glycol into the Lake until the onshore pumps were shut down.

1.148
Once released into the Lake, liquids would disperse through solution, emulsification, or formation of an insoluble liquid layer. Solids with densities exceeding that of lake water would settle to the lakebed. Depending on their physical and chemical properties, they could remain in the sediments or dissolve into the water. The greatest fraction of gases released into the Lake would bubble to the surface. Depending on the properties of the gases and lake water, some portion of the gases could be expected to dissolve into the water.

1.149
A number of accident categories were further investigated to provide realistic assumptions to describe how specific materials or residuals could be released to the environment. These assumptions (see Appendix C) were used as the basis for modeling concentrations of representative pollutants in the Lake at the point of release and 0.5 mile from the accident.* This modeling effort was used to help assess impacts to water quality resulting from accidental release of materials and residuals.

Economic Feasibility Analysis

Purpose and Scope of the Analysis

1.150
The economic evaluation was conducted to determine whether Lake Erie natural gas development would be viable under the conditions set forth in the Reference Program. The evaluation is flexible; a number of environmental or other costs can be added or deleted from the program to test economic viability under various regulatory conditions.

1.151
The analysis relies on net present value and rate of return on investment as measures of feasibility. Although the evaluation method can indicate whether the Reference Program is economically feasible, it cannot predict which operators might be attracted to drilling, whether other drilling prospects outside the region might be more attractive to these operators, or whether one or more operators would show interest in Lake Erie development. The above competitive aspects of resource development are beyond the scope of this EIS.

Time Frame

1.152
The economic evaluation attempted to simulate development activity over a period of years, with the productive life of individual wells being 15 to 20 years. The Reference Program and subsequent economic feasibility analysis was initiated in 1980 to maximize the use of cost data based on known trends. In the absence of actual drilling proposals from the private sector, the analysis was based on accelerated development with reasonable operation and siting constraints. Any departure from the development scenario would increase the time frame over which impacts would occur.

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*Potential impacts of routine or accidental releases of materials or residuals on Lake Erie potable water quality was identified as a major public issue in early assessment work (McGregor et al. 1978). The Reference Program was designed to keep all routine activities at least 0.5 mile from potable water intakes. Estimates of pollutant concentrations at 0.5 mile from point of release describe water quality conditions at potable water intakes resulting from Reference Program accidents. If the accident were to occur in the immediate vicinity of an intake, pollutant concentrations at point of release provide a worst-case order-of-magnitude comparison.

Estimated Price of Lake Erie Gas

1.153
The natural gas price projection for the Reference Program takes into account the suggested wellhead ceiling price for new natural gas of the Natural Gas Policy Act of 1978. Based on the initial ceiling price of $1.75/million Btu* for new gas as of April 20, 1977, the price in 1980 has been projected to be $2.47/million Btu.* This price has been escalated at the rate of 11.2% between 1980 and 1985, 8.96% between 1985 and 1990, 8.76% between 1990 and 1995, and 8.63% for the over-1995 period (Data Resources, Inc. 1979). The rate of escalation for the price is conservative when one compares the price increases for the alternate fuels (e.g., #2 oil or #6 oil, etc.), especially for the period 1985-1990. The price of natural gas may rise faster than projected in the present analysis. The free market will equilibrate the price of natural gas with its alternative fuels (on a Btu basis).

Production Information

1.154
As noted in Table 1-4, the key production information used in the assessment includes: depth to reservoir, success ratio (65 to 90%), productive life of wells, and initial and average production rates. Both production rates and success rates were assessed for sensitivity to economic feasibility. A production decline curve was developed for the Clinton-Medina sandstones and Lockport reefs. These curves are presented in tabular form in Tables 1-5 and 1-6. Annual (Figure 1-18) and cumulative state production (Table 1-36) were estimated for both 288-day and 360-day drilling seasons.

Geographical Coverage

1.155
The Reference Program Study Region was divided into 16 lease areas. Each area was examined separately for economic viability because estimated gas production and relative development and production costs are highly variable from area to area. The program allows separate evaluation of each state's resources. The terms and conditions of each state's existing or assumed lease conditions, including rental fees and royalties, are incorporated into the evaluation. State revenues generated by Reference Program activities are presented in Figure 1-19.

Allocation of Drilling Equipment and Capital Resources

1.156
Eight rigs (five jack-ups and three floaters) were allocated to drill lease areas over the life of the program. The actual deployment of rigs is depicted in Table 1-17. All facets of the geologic, engineering, and administrative assumptions are summarized in Tables 1-18 to 1-20. The primary costs are incurred during developmental well drilling and during construction of underwater pipelines and shore facilities. In order to develop a reasonably comprehensive cost data set, a sequence of Reference Program development activities was suggested as shown in Table 1-21.

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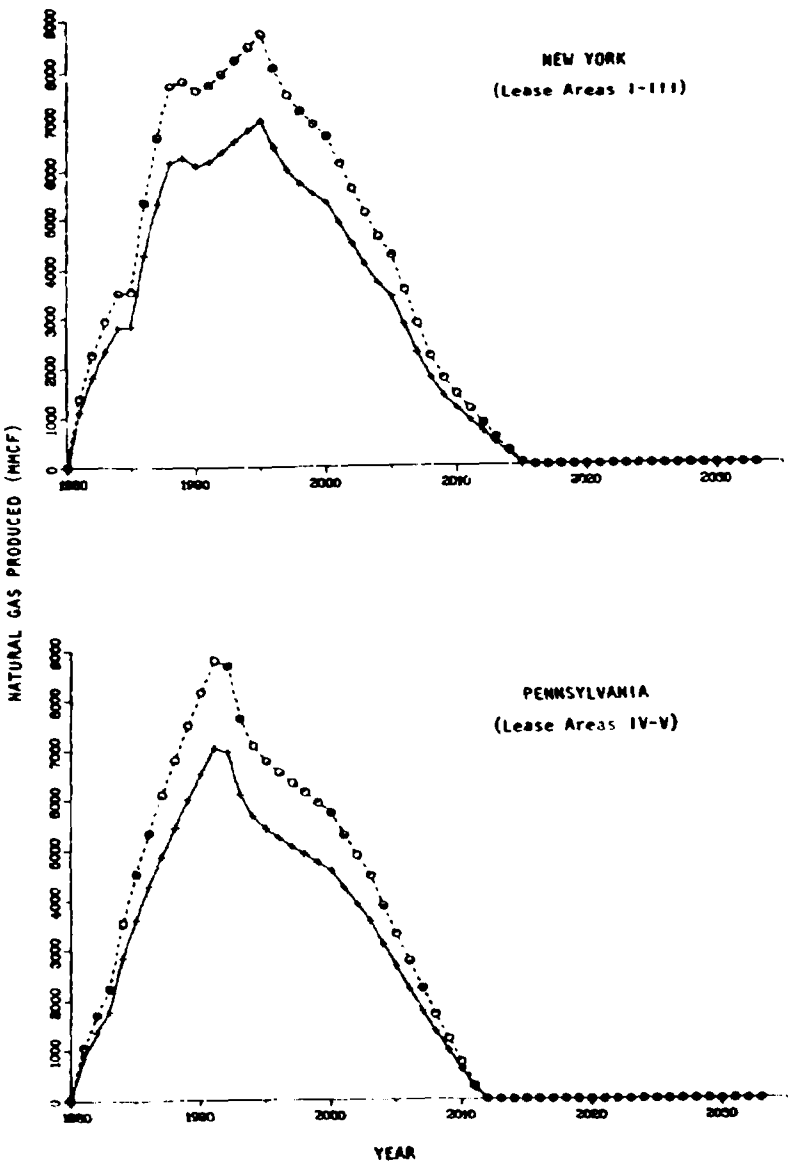
*Approximately 1 MCF of natural gas.



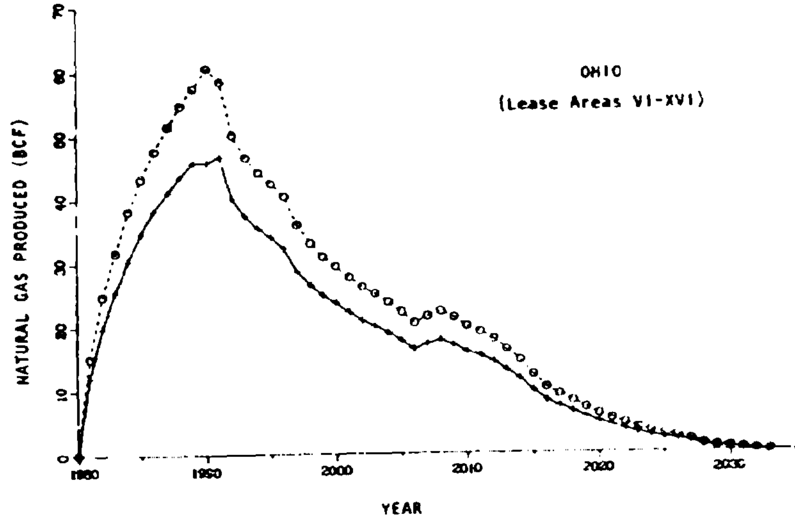


Figure 1-18.

Annual Gas Production from New York, Pennsylvania, and Ohio Waters of Lake Erie According to Reference Program Assumptions. Solid line = 288-day production year; dashed line = 360-day production year.

Table 1-36. Reference Program Total Natural Gas Production and Indicators of Financial Viability for Each Lease Area[a]

Lease Area	Production Interval	288-Day Production Without Glycol Injection			360-Day Production With Glycol Injection		
		Total Gas (BCF)	NPV[b]	ROI[c]	Total Gas (BCF)	NPV[b]	ROI[c]
N.Y.							
I	1986-2008	28	48	43	35	64	55
II	1981-2004	38	66	42	48	88	53
III	1986-2015	67	91	30	84	130	38
Pa.							
IV	1984-2011	47	59	24	58	87	30
V	1981-2011	71	110	31	89	160	39
Ohio							
VI	1990-2020	63	66	23	78	100	29
VII	1993-2023	54	27	15	67	56	19
VIII	1993-2024	60	28	15	75	60	19
IX	1992-2015	56	62	23	70	93	30
X	1993-2015	45	49	23	56	74	29
XI	1984-2011	50	66	27	62	95	34
XII	1997-2026	50	16	13	62	41	17
XIII	1981-2006	210	410	86	270	540	105
XIV	1981-2005	330	660	100	410	850	120
XV	2007-2028	26	40	62	32	52	67
XVI	2008-2033	31	41	47	39	56	56

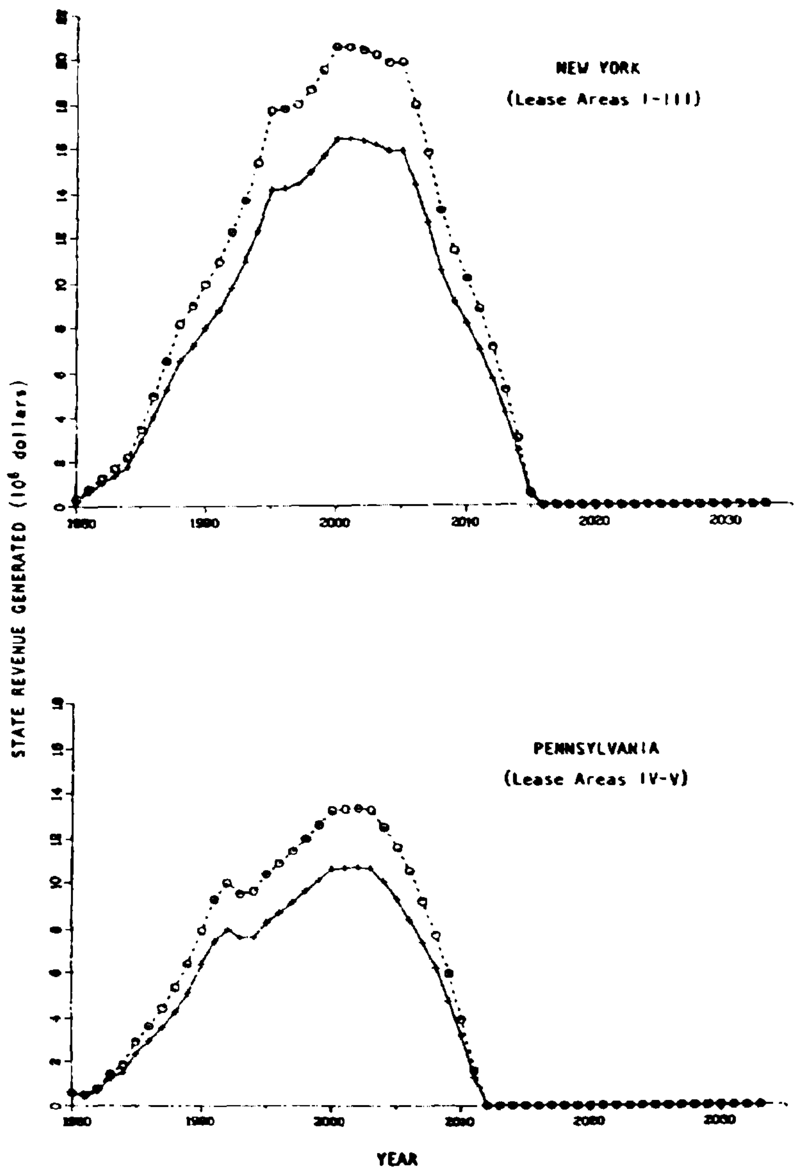
[a]Rate used to escalate drilling cost = 12%; rate used to escalate other costs = 7%; discount rate for present value calculation = 10%.

[b]Net present value in millions of dollars in the first year of production.

[c]Rate of return on investment.

Cost Information

1.157
Cost information used in the evaluation is summarized below. These costs are summed in appropriate categories in Table 1-37. Drilling costs for productive and unproductive wells were included in the analysis. Costs were evaluated for routine and construction activities. Routine activities include the development, operation, and maintenance of the wells, and the operation and maintenance of production facilities and pipelines. All construction costs include material and labor requirements. The cost of waste treatment and disposal--i.e., land acquisition, facility construction, waste transportation, operation, and maintenance--was not evaluated due to the preliminary nature of the waste management strategy suggested. Based on treatment costs reported by



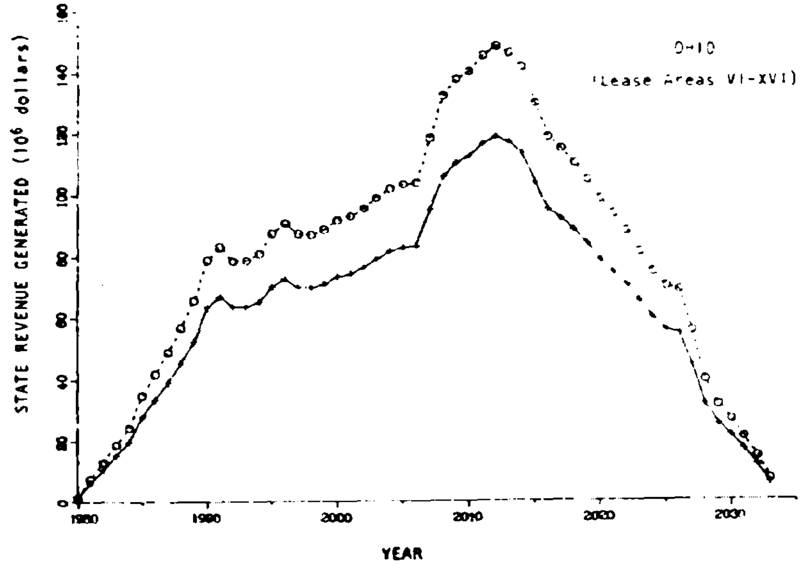


Figure 1-19.

Annual State Revenues Generated by Reference Program Activities in New York, Pennsylvania, and Ohio Waters of Lake Erie. Revenues include cash bonus bids, rental fees, and royalty fees required of operators. Solid line = 288-day production year; dashed line = 360-day production year.

Table 1-37. Cost Estimates (1979 dollars) for Developing U.S. Lake Erie Natural Gas According to Reference Program Assumptions

Lease Area	Drilling[a] per Prod. Well	Drilling[a] per Dry Well	Gas Collection System per Prod. Well[a] Without Glycol Inj.	Gas Collection System per Prod. Well[a] With Glycol Inj.	Gas Processing and H_2S Stripper Facility[b]	Compressor[c]	Decomm. per Prod. Well[d]	Operation and Maintenance per MCF[e]	Royalty Payment[f]	Cash Bonus Paid per Acre[b]	Delay Rental per Acre per Year[g]
I	166,600	100,600	38,200	48,900	101,400	141,100	10,100				
II	166,600	100,600	50,100	62,700	110,600	170,100	10,100		0.167		2.0
III	211,800	163,900	50,100	62,500	136,600	279,900	28,000				
IV	246,600	194,100	50,100	62,700	114,000	194,600	28,000		0.125		1.0
V	199,900	129,300	50,100	62,600	137,800	296,700	10,100				
VI	210,100	138,200	74,000	90,400	129,300	255,700	10,100	0.2		3.0	
VII	259,600	205,900	74,000	90,400	116,200	212,700	28,000				
VIII	259,600	205,900	74,000	90,400	123,600	234,200	28,000				
IX	210,100	138,200	50,100	62,700	140,600	251,200	10,100				2.0
X	210,100	138,200	50,100	62,700	129,800	206,900	10,100		0.167		
XI	210,100	138,200	50,100	62,700	117,800	207,000	10,100				
XII	259,600	205,900	74,000	90,500	113,400	199,500	28,000				
XIII	251,200	199,200	88,300	103,700	7,504,100	555,000	28,000			4.0	
XIV	201,800	131,700	56,000	67,400	11,748,100	946,300	10,100				
XV	66,600	0	0	0	0	0	10,100			3.0	
XVI	91,600	0	0	0	0	0	28,000				

[a] Yearly cost, each drilling year from first year of drilling.
[b] One-time cost, first year of drilling.
[c] One-time cost, second year after peak production.
[d] One-time cost, last year of production.
[e] Cost every production year.
[f] Percent of gas value, every production year.
[g] Each drilling year except first and last years.

Specken (1975) for similar wastes, the absence of waste treatment/disposal costs from the economic feasibility evaluation would not significantly affect predicted Reference Program financial viability.

Investment Criteria

1.158
Net present value (NPV) and rate of return on investments (ROI) have been used as measures of the financial viability of the Reference Program. If there is ample investment capital available, use of either NPV or ROI should give the same results upon analysis. But, if investment capital is limited, NPV is superior to ROI in ranking different investment projects. Rate of return on investment implicitly assumes reinvestment at the calculated rate of return whereas ranking by use of net present value implicitly assumes reinvestment at the cost of capital. The provision of both (NPV and ROI) results would give the decision-maker a basis for making project acceptance/rejection decisions. In the present analysis, payback period as the basis for investment decision has not been emphasized. The Lake Erie Reference Program is very time dependent. The investments occur mostly over the drilling years, and the gas revenue is obtained for 15- to 20-year periods. Payback period, defined as the length of time necessary for the sum of the annual net cash benefits to equal the initial investment, is not very meaningful. The payback period ignores the time value of money, fails to consider any stream of income extending beyond the payback period, and has no means of adjusting for different scales of investment. Under the present situation, payback period is even more unsuitable because the project analysis is before tax, whereas the annual net cash benefit traditionally used in the payback period calculation is after tax net cash benefit.

1.159
The computer program developed to generate ROI and NPV is very flexible. Simulation runs of various assumptions can be easily generated by changing any of the input variables, (e.g., rate of escalation for price and cost, value of different cost components, rate of gas production, number of days of production, and period of drilling and production).

Results

1.160
The model was run for each lease area for two production scenarios: 288-day (Case I) and 360-day (Case II) production years. The results (Tables 1-36 and 1-38) show a positive NPV and an ROI higher than 13% for each lease area. The ROI ranges from 13 to 100% and 17 to 120% for Case I and Case II, respectively. From the financial point of view, investment for each lease area in each case of production is viable. The amounts of gas produced over the production period for New York, Pennsylvania, and Ohio are projected to be 133, 118, 975 BCF (Case I) and 167, 147, 1221 BCF (Case II), respectively. From this analysis, it appears that the Reference Program could produce as much as 1535 BCF of gas between the years 1981 and 2033. During this period, New York, Pennsylvania, and Ohio (under Case II assumptions) would collect a revenue (from cash bonus bid, delay rental, and gas royalties) of 406, 247, and 4290 million dollars, respectively.

Table 1-38. Reference Program Gas Production, Total Investments, and Net Revenues

Lease Area	Drilling Interval	Production Interval	288-Day Production Without Glycol Injection: Total Investment[a] (10^6 \$)	Total Gas Produced[b] (BCF)	Net Gas Revenue[c] (10^6 \$)	360-Day Production With Glycol Injection: Total Investment[a] (10^6 \$)	Total Gas Produced[b] (BCF)	Net Gas Revenue[c] (10^6 \$)
N.Y.								
I	1985-1988	1986-2008	32	28	370	33	35	460
II	1980-1984	1981-2004	28	38	340	28	48	430
III	1985-1995	1986-2015	160	67	1200	160	84	1500
Pa.								
IV	1983-1991	1984-2011	110	47	670	110	58	840
V	1980-1991	1981-2011	110	71	900	110	89	1100
Ohio								
VI	1989-2000	1990-2020	290	63	1700	290	78	2100
VII	1992-2003	1993-2023	480	54	1900	480	67	2400
VIII	1992-2004	1993-2024	580	60	2200	580	75	2800
IX	1991-1995	1992-2015	210	56	1300	210	70	[illegible]
X	1992-1996	1993-2015	180	45	1100	180	56	[illegible]
XI	1983-1991	1984-2011	100	50	710	100	62	890
XII	1996-2006	1997-2026	650	50	2300	650	62	2900
XIII	1980-1991	1981-2006	150	210	1700	150	270	2200
XIV	1980-1990	1981-2005	180	330	2500	180	410	3200
XV	2006-2008	2007-2028	110	26	1900	110	32	2400
XVI	2007-2013	2008-2033	260	31	3000	260	39	3800

[a]Total investment over the drilling period.

[b]Total gas produced over the production period.

[c]Total net gas revenue over the production period.

1.161
When the model was run with a 20% decrease in the rate of production from original production estimates, the ROI ranged from 10 to 81% and 13 to 100% for Case I and Case II, respectively. The NPV was positive for each lease area in every case except for Lease Area XII, Case I (288 days).

Discussion

1.162
Since the results of this economic analysis are strictly dependent on the assumptions made to drive the model, reasonable variations in assumption are presented below to identify potential model weaknesses and strengths.

- The Reference Program is economically viable for an industry operator even if the rate of production is 20% below the estimated rate. A higher error in the estimated rate of production may render the project uneconomical. Since the natural gas price projection in the current analysis is very conservative, there is a very low probability that the actual economic benefits would be lower than the current projection.

- Success ratios of 85, 70, and 65% have been assumed for New York, Pennsylvania, and Ohio Clinton-Medina sandstones; a success ratio of 90% has been assumed for Ohio Lockport reefs. An error in these estimates (lower/higher) would affect the current result.

- A change in rate of assumed cost escalation (high/low) would influence the result. However, a higher rate of cost of escalation would possibly be compensated by a higher rate of increase in the price of gas.

- The analysis assumes that there is a demand for U.S. Lake Erie gas at the estimated price. In the absence of demand at the projected price, this economic analysis does not have much meaning.

- The net cost flow used in the analysis is before tax, and no depletion allowances have been considered in the calculation. As a consequence of these opposite costs, the result would not be very different.

- The cost of onshore transportation of waste between dock and treatment/disposal facility and of treatment and disposal of these wastes is not included in the total cost of developing Lake Erie gas. Because this is a small percent of the total cost of the project, it should not influence the overall profitability.

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CHAPTER TWO: ALTERNATIVES TO THE PROPOSED ACTION

SELECTION OF ALTERNATIVES

2.001
As described in Chapter One (Definition of the Proposed Action), in the strictest sense there is only one action and one alternative under consideration in this EIS. The action alternative is defined as the issuance of permits by the Corps and USEPA to lessees engaged in state-initiated development of offshore gas in Lake Erie; the no-action alternative includes those decisions that would prevent the development of natural gas beneath U.S. waters of Lake Erie. This could result from (1) denial of or recommendation for denial of permits by the Corps and/or USEPA, (2) denial of state permits and leases, (3) establishment of drilling bans by state legislatures, or (4) operator decisions to postpone or cancel any consideration of development. Implementation of the no-action alternative by any of the above means would eliminate all primary and secondary impacts and any derived benefits associated with gas development in the Lake. Options within the no-action alternative include (1) development of alternative supplies of natural gas, (2) supplementation of existing supplies through increased use of gas derived from coal and other potential fuel resources, and (3) reduction of existing demand through energy conservation.

2.002
Both conventional and unconventional natural gas reserves are found within the Lake Erie region, and natural gas can be shipped to the region through existing pipelines under favorable economic and regulatory conditions. In addition, substitutes for natural gas could extend natural gas supplies, depending upon technological advances and economic constraints governing development of synthetic gas. Other alternatives to the proposal to allow Lake Erie natural gas lease sales would result from elimination of excess demand by voluntary conservation. The most reasonable alternatives arising from predictions of increased supplies, extended supplies, or reduced demand depend upon the effects of regulatory policy as well as projections of regional economic and industrial development. Two important regulatory actions are the National Gas Policy Act and the 533 Program allowing self-help gas production, which are expected to encourage increased domestic natural gas production in the 1980s.

2.003
The Natural Gas Policy Act (NGPA) of 1978 is a comprehensive and substantive revision of natural gas pricing and regulation. A major provision of the act (one of the five components of the National Energy Act) is a gradual move towards price deregulation of newly discovered natural gas in 1985. New gas, defined as gas from wells drilled on or after February 19, 1977, will be allowed to increase from a base (established in April 1977) price until 1985 when it will be completely deregulated. Old gas will never be deregulated, but will be allowed to increase in price to compensate for inflation. Furthermore, the act abolishes the dual market system for interstate and intrastate gas; intrastate gas (gas produced and sold in the same state) is placed under federal controls for the first time.

2.004
A major purpose of the NGPA was to allow the wellhead price of natural gas to increase in order to provide adequate economic incentive for producers to increase production. Presently, there are no production data available to

ascertain the impact of NGPA on domestic gas supply, nor will these data be available until the early 1980s. There are, however, indicators of significant increases in exploration and drilling activity which should, in the short term, result in increased domestic gas production. Gas well completions in 1978, for example, were at an all-time high, and well completions for the first six months of 1979 were 14.2% greater than the first six months of 1978 (Am. Gas Assoc. 1979b). According to the American Gas Association (AGA), drilling activity has increased 15-25% since the passage of NGPA. In addition, the amount of gas dedicated to interstate pipeline companies has been increasing, which would indicate that the abolishment of the dual market system is improving the regional supply situation.

2.005
Average wellhead prices for new gas have increased by 30% (October 1979, $2.29/million Btu) since enactment of NGPA. By 1984, the last year of price regulation, new gas prices will increase by at least 88% (predicted price, $3.30/million Btu) from a base price of $1.75/million Btu established in April 1977.*

2.006
As gas prices continue to escalate, drilling activity should increase in frontier areas where historically low wellhead prices have largely precluded development. The possibility of finding significant new gas reserves are highest in frontier regions (Am. Gas Assoc. 1979a). Increasing wellhead prices should stimulate the development of these resources, thereby improving the nation's domestic gas supply situation.

2.007
The Federal Energy Regulatory Commission (FERC) has encouraged the development and interstate movement of natural gas by companies facing gas curtailments. The 533 Program (FERC--Order 533) allows the direct purchase of natural gas by a commercial or industrial consumer. The sale is a direct retail sale transaction, contracted by the company, and the gas is moved by existing interstate pipeline facilities. The 533 Program was originally intended to allow high priority (Priority 2) end-users, whose natural gas supplies were curtailed or in danger of curtailment, to secure supplies of gas on their own initiative.

2.008
One of the problems with self-help gas is the expense to the end-user. In addition to production cost, the end-user must pay for use of existing metering and gathering facilities. Also, pipeline companies charge transportation fees and require the consumer to permit the retention of a percentage of the 533 volumes. Despite the expense, the 533 self-help program has been used by a number of commercial and industrial end-users, and has meant the difference between continued production or plant closings for many companies. This was particularly the case for participating companies during the winter seasons of 1976-77, and 1977-78 (Buck 1978).

*Data are from the American Gas Association (1979d). It should be noted that predicted prices by the American Gas Association have already been superseded. The predicted price for new gas, 1979, was $2.09/million Btu whereas the October 1979 price was $2.29/million Btu, a price which exceeds the AGA 1980 estimate for new gas.

2.009
Many states have similar self-help programs patterned after FERC Order 533. Ohio, in particular, has had considerable success in encouraging end-users to secure their own source of supply and move the gas through an intrastate pipeline (DeBrosse 1975). Contracted gas enters the pipeline at the wellhead and the company is then allowed to draw out an equivalent amount of gas at the plant site. Some companies in Ohio and Pennsylvania have drilled for gas on their own property, but most have sought the services of independent producers who obtain leases for potential drilling sites. In Ohio, in addition to the expense of contract drilling, companies obtaining self-help gas must pay the utility company 25% of the gas from each well plus a transportation fee. Following the severe gas curtailment period of January-February 1977, many companies in the Reference Program Study Region were actively pursuing self-help gas. Some of this activity has ceased, partly because of the expense of self-help gas and partly because of the assurances of adequate gas supplies from the utility companies. However, self-help gas is a major source of gas supply for many companies in the tri-state region. In Ohio, approximately 28 BCF of gas were obtained through industrial self-help activities in 1978. This represents about 24% of the total gas produced in the state for that year (DeBrosse 1979--personal communication).

2.010
Self-help gas can provide additional sources of gas supplies, sometimes substantial volumes, as evidenced by the Ohio case. It is not, however, a solution for maintaining adequate gas supplies to many industries. There is considerable expense involved in self-help gas and many companies, particularly smaller ones, cannot financially assume these costs. Nor is self-help gas a short- or long-term solution to regional gas demands. These demands will have to be met in the longer term by utilities which plan and invest for a mix of gas supply from both traditional and nonconventional sources.

Alternative Lake Development Programs

2.011
The proposed action under consideration is the issuance of permits by the Corps and USEPA to lessees engaged in state-initiated development of offshore gas in Lake Erie. The Reference Program details how development of the leases might proceed if certain practices protective of the lake environment were to be used. If the Reference Program is found to be acceptable after public and agency review, it could form the foundation for decisions on handling lease sales and permits. Suggested technological specifications and regulations for development will require approval by the Corps and USEPA and, finally, approval by each state and federal agency involved in the program. The Reference Program does not represent a specific proposal to drill in the Lake, and in the absence of a development program proposal from industry with detailed technological specifications, alternative development programs in Lake Erie cannot be considered. In such a complex technology as gas development, it is unreasonable to describe and compare the consequences of all methods used without a proposed drilling program from which suitable alternatives can be generated. Future specific proposals by industries that differ considerably from Reference Program technology and standards would have to be evaluated on a case-by-case basis during permit application processing.

2.012
In the process of investigating all alternatives to offshore development of U.S. Lake Erie gas, the potential for drilling from land-based sites into natural gas reserviors beneath the Lake was considered. Due to (1) technological limitations constraining great deviations away from a vertical line connecting the wellsite and target reservoir, and (2) the relatively shallow depths of target reservoirs beneath the Lake, the onland wellsite would have to be located a great distance inland from the lakeshore in order for the wellbore to encounter offshore Devonian and Silurian strata. The cost of drilling such a directional well would be significantly greater than for conventional wells and would probably be prohibitive in the context of anticipated revenues from produced gas. Also, complications could be expected from the acquisition of lease rights along onshore corridors required to gain access to geologic strata beneath the Lake; the land surrounding the southern shore of Lake Erie has already been extensively leased. Consequently, directional drilling was dismissed from further consideration as a viable developmental option to the Reference Program.

Alternative Sites

2.013
Portions of the Lake were eliminated from the Reference Program because unacceptable environmental impacts could be incurred if drilling were allowed in these areas (see Table 1-7). These constraints include (1) greater probability of striking oil-bearing strata in the western basin of the Lake, (2) use conflicts in areas of gravel and sand deposits, and (3) program interference with municipal, fishery, and recreational use of nearshore waters. All other areas of the Lake under the jurisdiction of the United States are part of the leasing program. Thus, no reasonable alternative sites for lease sales in the Lake remain, and the issue of alternative lease sites cannot reasonably be addressed.

Alternative Supplies of Natural Gas

Regional Land-Based Resources

2.014
Estimated proved reserves for New York, Ohio, and Pennsylvania were 3.9 TCF of natural gas as of December 1978 (Am. Gas Assoc. 1979c). Pennsylvania had the highest volume of proved reserves estimated to be about 2.1 TCF. Production from conventional land-based drilling in the tri-state area produced an estimated 202 BCF of natural gas in 1977. This represents an increase in gas production of about 7.3% (14.7 BCF) from the previous year. Ohio and Pennsylvania were the major producing states with a gross production of 99.7 and 91.8 BCF, respectively, in 1977 (Am. Gas Assoc. 1979c).

2.015
Trends in production from conventional land-based drilling in the states bordering Lake Erie point to continued increases in state-produced natural gas supplies. Between 1970 and 1977, gas production within New York, Pennsylvania, and Ohio increased by 52%, and the number of new gas wells drilled increased by 186% (Table 2-1). Significant increases in wellhead price, resulting from the Natural Gas Policy Act of 1978 (NGPA), should stimulate the search for additional gas fields. Prior to NGPA, the average wellhead price

Table 2-1. New Gas Well Completions in New York, Pennsylvania, and Ohio, 1970-1978[a]

State	1970	1975	1976	1977	1978
New York	17	236	355	256	224
Pennsylvania	250	640	565	694	1106
Ohio	683	555	1121	1371	1390

[a]Data from American Gas Association (1978).

for gas in the United States (1977) was approximately $0.79/MCF (Am. Gas Assoc. 1979c). In 1978, the average wellhead price paid by Columbia Gas Transmission Corporation and Consolidated Natural Gas Company for Ohio (Appalachia)-produced gas was $1.26/MCF and $1.29/MCF, respectively. In the first quarter of 1979, Columbia Gas Transmission was paying $1.90/MCF (wellhead) for Appalachia-produced gas whereas Consolidated was paying $1.65/MCF [personal communication (1979) with Columbia Gas Transmission Corporation and Consolidated Natural Gas Company].

2.016
At the present time there is a surplus of natural gas in the tri-state region and producers may encounter some difficulty in marketing new gas. For example, Consolidated Natural Gas Company noted in its Annual Report (1978) that "because of the temporary excess supply of natural gas nationwide and a desire by the company to reduce capital expenditures where possible, company financed new drilling programs in the Appalachian region will be reduced in 1979 from the accelerated levels of recent years to more normal levels. Similarly, there will be a reduction in the number of new gas purchase wells attached to our lines in 1979" (Consolidated Nat. Gas Co. 1978). In the short term, this temporary surplus may discourage the search for new gas. In the longer term, however, as excess supplies decline higher wellhead prices should accelerate land-based drilling programs and producers should encounter favorable market conditions for new gas in New York, Pennsylvania, and Ohio.

Domestic Conventional Reserves

Alaskan Gas

2.017
Large amounts of natural gas are present in Alaska's petroleum-rich north slope. An estimated 26 TCF, or 10%, of the nation's proved recoverable natural gas resources are in the Prudhoe Bay field. Other areas of the state have not been fully explored for their gas potential but exploration efforts to date indicate that considerable gas will be found in other regions (Bergeson 1978). The U.S. Geological Survey estimates that between 16 to 57 TCF (95 to 5% probability, respectively) of natural gas may yet be discovered within the state (Miller et al. 1975). Natural gas presently produced in the Prudhoe Bay field is being reinjected into a reservoir, a procedure which will continue until the gas can be transported to markets.

2.018
A major bottleneck in Alaska gas production has been transporting the gas to markets in the lower 48 states. In 1977, an agreement was reached between the United States and Canadian governments with respect to building a natural gas pipeline from Alaska through Canada to midwestern and western U.S. markets. The Alaska Highway Pipeline route was chosen by the two governments to minimize environmental impacts and to maximize the use of existing transportation networks. The 48-in. diameter natural gas pipeline will parallel the Trans-Alaska crude oil pipeline for some 539 miles from Prudhoe Bay to south of Fairbanks. From there it will turn southeast to parallel the Alaska Highway to Canada where it will cross the Yukon Territory and continue south through Canada. North of Calgary, the pipeline will fork, entering the United States in two branches. One line will extend east into midwestern markets and terminate in northeast Illinois; a western leg will move gas to the San Francisco Bay area. The 4753-mile pipeline is designed to carry an initial capacity of 2.6 BCF/day, about 5% of current domestic supply (the pipeline could handle 3.4 BCF/day with additional compression). The cost of the Alaska Highway Pipeline is an estimated $10 billion, but some estimates speculate the project could cost as much as $15 billion. Construction of the pipeline is to begin in 1981 with a completion date scheduled for early 1983 (Am. Gas Assoc. 1978c).

Outer Continental Shelf Reserves

2.019
The Outer Continental Shelf (OCS) is the gently sloping portion of the continental margin extending from land to a depth of approximately 600 ft. By law, the OCS is defined as that area beyond the states' territorial waters (3-mile limit, except for three leagues off Texas and West Florida) out to 200 miles (Conserv. Found. 1977). Approximately 7% of total U.S. cumulative gas production has come from OCS sources.

2.020
In 1977, offshore gas accounted for about 22% (4.5 TCF) of total U.S. production (Am. Gas Assoc. 1979c); most industry spokesmen agree that as existing onshore reservoirs decline, much of the short-term gas supply is expected to come from increased OCS production (Samsa et al. 1977). Offshore regions of the United States are estimated to contain undiscovered recoverable gas resources of 42 to 181 TCF. There is a 95% probability that at least 42 TCF of natural gas can be produced from offshore locations (Table 2-2).

2.021
In the short term, increased gas production from offshore sources will probably come from the Gulf of Mexico. A highly developed oil and gas industry exists along the Gulf coastal area, and the region has a long history of gas production which includes years of extensive geologic data gathering. The infrastructure for further development is present and the area is connected to midwestern and eastern markets with an extensive pipeline transmission system. OCS production from the Gulf comprised over 17% of total U.S. natural gas production in 1975 (Conserv. Found. 1977). Miller et al. (1975) estimated that over 35 TCF of natural gas reserves are in the Gulf of Mexico, and significant incre[illegible] production could be realized within a few years.

2.022
Significant natural gas production from other OCS leases could take much longer to develop. There is considerable speculation that Alaska's basins,

Table 2-2. Production, Reserves, and Undiscovered OCS Resources (in TCF)[a]

Region	Cumulative Production To Date[b]	Demonstrated (Measured) Reserves	Inferred Reserves	Undiscovered Recoverable Resources: Statistical Mean	Undiscovered Recoverable Resources: Est. Range (95-5%)
Alaska	0.423	0.145	0.1	44	8-80
Pacific Coastal States	1.415	0.463	0.4	3	2-6
Gulf of Mexico	32.138	35.348	67.0	50	18-91
Atlantic Coastal States	0.000	0.000	0.0	10	5-14
Total lower 48 offshore	33.553	35.811	67.4	63	26-111
Total offshore U.S.	33.976	35.956	67.5	107	42-181

[a]Data from Miller et al. (1975).

[b]Through December 31, 1974.

especially those in ice-locked locations, contain sizable gas reserves. Excluding environmental constraints, there is a strong likelihood that some Alaskan OCS fields (e.g., Beaufort Sea) could be developed in a relatively short time span since these areas represent a continuation of onshore fields. It could, however, take at least ten years before production could commence from many OCS Alaskan leases (Clark et al. 1978). Other offshore regions of the United States have lower probabilities of significant gas finds, and any production from these potential fields will take many years to develop. These "frontier" regions (Mid-Atlantic, for example) are not offshore extensions of onshore fields, nor is the infrastructure present to handle the transmission of gas.

2.023
The technology is available to significantly increase natural gas production from several OCS locations. In the short term, most increases in OCS gas production will come from the Gulf region. It is estimated that as much as 18-91 TCF in undiscovered gas resources underlie the region. Significant gas production from other OCS leases, particularly the frontier areas, are years away.

Domestic Unconventional Reserves

Devonian Shales

2.024
Devonian shales underlie much of the Appalachian basin of the eastern United States. Almost 3 TCF of gas has been produced from shales since the turn of the century with proved reserves estimated at about 1 TCF. The most important producing areas are in Kentucky, West Virginia, and Ohio. In 1976, these states produced an estimated 0.1 TCF of natural gas from Devonian shales (Kuuskraa et al. 1978).

2.025
The most persistent problem encountered in the production of natural gas from Devonian shale is the lack of adequate permeability. Gas production is largely

controlled by naturally occurring fractures or bedding planes from which gas is released when they come into contact with the wellbore. Gas flow rates from shale wells are typically lower (30 MCFD) than conventional wells but their cumulative production can be significant over the life of the well (Am. Gas Assoc. 1978b). Most of the gas is absorbed within the shale matrix and is not producible by conventional drilling. Studies estimate that only 2-10% of the original gas in place is recoverable. The remaining 90-98% of the gas resource requires some type of enhanced recovery system (Potential Gas Comm. 1979). In recent years, hydraulic fracturing has been used to enhance gas flow. In this method, a fluid is pumped into the wellbore at increased pressure until the breakdown point is reached and fractures are created in the rock. Sand is generally injected into the well where the particles act as a propping agent to prevent the closure of fractures when the pressure is released.

2.026
Estimates of potential gas recoverable from Devonian shales vary widely. Estimated recoverable volumes range from 1.7 to 903 TCF using existing drilling and stimulation techniques (Potential Gas Comm. 1979). The U.S. Geological Survey has estimated a total in-place Devonian gas resource of 500-600 TCF (Am. Gas Assoc. 1978b). The Columbia Gas System, which has done considerable work on Devonian shale, estimates that about 285 TCF may be recoverable in the Appalachian area with existing technology.

2.027
Increased natural gas production from Devonian shales is dependent upon a combination of improved technology and higher prices.* Directional drilling to intercept natural fractures and the application of remote sensing to detect surficial joint or fracture patterns are examples of new technology. Increased Devonian gas production is also highly sensitive to price. An analysis by the Office of Technology Assessment estimated that wellhead prices for Devonian gas in the $2-3 MCF range may be sufficient to produce 15-25 TCF of Devonian shale gas using conventional technology with hydraulic fracturing (Am. Gas Assoc. 1978b).

2.028
In the short term, enhanced production of natural gas from Devonian shales in the Appalachian basin would increase regional supplies of gas. In the long term, Devonian shale gas would have to be more extensively produced to meet increasing demands at a time when production from conventional gas sources is declining.

Land-Based Tight Sands

2.029
Large quantities of gas are known to exist in tight sand formations of low permeability which extend from western Louisiana intermittently through Texas

*Producers maintain that shale wells are more expensive to drill than conventional wells. In "any given year there is approximately a 27% cost increase in drilling average shale wells over the national average cost for similar, more conventional wells. This additional expense may be attributed to locally rugged terrain, additional casing required to protect coal seams, and remote locations relative to many service companies" (Potential Gas Comm. 1979).

to the Unita Basin in Utah and the southern Great Plains. At least 20 tight sand reservoirs have been identified and data are available on 13 (Kuuskraa et al. 1978). Most potential tight sand reservoirs consist of sandstones or siltstones interbedded with shales and are often of limited lateral extent. Considerable volumes of gas are contained within these formations, but the low permeabilities and the discontinuous nature of most reservoirs have largely precluded production under prevailing economic conditions (Potential Gas Comm. 1979).*

2.030
Tight sand gas reservoirs are currently producing natural gas. An estimated 1 TCF of natural gas were produced from tight gas basins in 1976 (Kuuskraa et al. 1978). The major problems associated with increased production are permeability enhancement and formation evaluation. Two methods of permeability enhancement have been investigated: nuclear explosive stimulation and massive hydraulic fracturing.

2.031
Three nuclear stimulation experiments were conducted in tight sand formations between 1967 and the early 1970s. The objective was to create a rubble chimney which would act as an enlarged wellbore. These tests were abandoned due to low gas recovery, high costs, potential environmental hazards, and public concern over the dangers of radiation. Massive hydraulic fracturing involves the injection of large volumes of fluid and proppant (sand) into a well under high pressure. The objective is to create and maintain massive fractures which enhances the flow of gas. This method has been successfully employed in a number of tight sand reservoirs and appears to be particularly effective in blanket-type tight sand formations. Its usefulness, however, under other conditions, such as lenticularity, has yet to be proven (Kuuskraa et al. 1978).

2.032
An estimate of a gas-in-place resource of 600 TCF has been commonly quoted for western tight sand reservoirs, with recovery rates of 40-50% using advanced stimulation techniques (Potential Gas Comm. 1979). Other estimates place the resource between 242 and 793 TCF. Between 70 to 300 TCF may be ultimately recoverable given adequate economic incentives and technological improvements. A combination of price incentives and federal-industry research and development could improve the recovery efficiency and accelerate the development of tight sand gas reservoirs.

Geopressured Aquifers

2.033
Geopressured aquifers refer to large water-bearing reservoirs which are characterized by higher temperatures and pressures than their depth alone would suggest. Under conditions of high pressure and temperatures, considerable methane may be dissolved in the trapped water, particularly if the water is

*Formations with permeabilities of less than 1.0 millidarcy are considered tight gas formations. Most western tight sands have average permeabilities of less than 0.05 millidarcy (Kuuskraa et al. 1978).

low in salinity. The objective is to produce the hot water under its own pressure, extract the methane, and dispose of the spent water in an economically and environmentally acceptable manner. Geopressured aquifers lie buried beneath the Gulf of Mexico and coastal regions of Texas and Louisiana.

2.034
Estimates of gas in-place for geopressured aquifers have been vast, ranging from 3,000 TCF to approximately 49,000 TCF (Potential Gas Comm. 1979). Because of the large estimates, considerable optimism has prevailed concerning the potential of this energy resource as a major contributor to the nation's natural gas supply. Research has indicated, however, that only a small percent, perhaps 2 to 5%, of the reservoirs' water can be produced before exhausting the reservoirs' drive mechanism. Thus, even under optimistic assumptions less than 5% of the gas resource may be economically recoverable (Kuuskraa et al. 1978).

2.035
Although the basic technology exists to produce hot, geopressured brines, it has never been tested and certainly not at high rates of flow, perhaps exceeding 100,000 barrels of water a day (Potential Gas Comm. 1979). At present, there are no commercial wells producing gas from geopressured aquifers and only two experimental attempts have been made (Potential Gas Comm. 1979). Thus, there is a lack-of-experience base and a number of technical and environmental problems to be solved before commercial production could commence.

Coal Seam Methane Gas

2.036
The occurrence of methane in coal has been the subject of investigation for many years. Methane in coalbeds poses a hazard to mining activities. Thus the main objective of most federal programs has been research aimed at coalbed degasification in order to control methane emissions and improve mine productivity and safety. Very little research has been conducted from the standpoint of collecting and storing methane as a potential source of gas supply.

2.037
Recoverable methane is presently considered economically producible only from working mines; methane production without mining is generally not feasible due to the substantial cost of surface equipment and gathering systems (Kuuskraa et al. 1978). The major resource is located in working, underground Appalachian mines where it is estimated that about 80 BCF of methane is vented each year (Kuuskraa et al. 1978).

2.038
There are several problems to overcome before the commercialization of coal gas can begin. Coalbeds have low permeabilities and degasification will require improvements in horizontal drilling techniques (Potential Gas Comm. 1979). Hydraulic fracturing has been used to enhance gas flow, but problems of mine safety remain. There are also legal problems associated with gas ownership, and gas deliverability rates are uncertain. Economics of the recovery system resulting from many collecting points and the treatment of a relatively small amount of gas from each mine remain unresolved (Potential Gas Comm. 1979). In general, the chemical composition of coalbed gas is marketable. Although no commercial recovery operations are currently collecting

coal seam gas, at least 80 BCF a year could be collected from mines in Appalachia. It is estimated that about 200 CF of methane can be found per ton of coal. Based on this average estimate, between 300 to 850 TCF of methane gas may be present within the coalbeds of the United States. The recoverable volume has been estimated at 200-250 TCF (Potential Gas Comm. 1979). With adequate economic incentives, the commercialization of coalbed gas could eventually provide a sizable energy resource for local or regional markets.

Imports of Foreign Gas

2.039
Natural gas trade between Mexico, Canada, and the United States began in the 1950s. Since 1958, the United States has imported more gas from Mexico and Canada than exported. Between 1959 and 1973, pipeline imports grew at an average rate of 16%, reaching a peak of over 1.0 TCF in 1973. In 1977, natural gas imports from Mexico and Canada slightly exceeded 1.0 TCF, representing about 5% of U.S. total natural gas supply (Energy Inf. Admin. 1977). In the short term, natural gas imports from these nations are expected to be nominal and at significant increases in price. This trend is expected to continue, a result of developing Mexican and Canadian policies and projected high internal demand for natural gas in these countries (Samsa et al. 1977).

Canada

2.040
Canada is the major source of imported pipeline gas to the United States. Canadian imports peaked in 1973 at a little over 1 TCF of natural gas and declined slightly since that time (Table 2-3). In 1978, Canadian natural gas imports totaled over 881 BCF. Canadian gas imports for the next several years are expected to continue a downward trend or stabilize at some relatively small quantity, probably less than 1.0 TCF (Samsa et al. 1977). Longer-term projections indicate that the amount of Canadian gas available for export will probably decline after 1985 (Energy Inf. Admin. 1977). Prior to October 1979, U.S. importers of Canadian natural gas were paying $2.80/MCF, but Canadian officials maintain that the export price will increase to match the price recently negotiated for Mexican gas (Washington Post 1979).

Mexico

2.041
Mexico has exported relatively small volumes of natural gas to the United States for about 25 years. The peak year was 1965 when approximately 52 BCF was exported to U.S. markets. In recent years (1975, 1976, and 1978), the United States did not import any natural gas from Mexico. After several years of negotiations, Mexico recently agreed to sell gas to the United States from discoveries in the Gulf of Mexico. According to the agreement, Mexico will export 300 MMCF of natural gas a day to U.S. buyers. The gas will be delivered to the United States by an existing pipeline from Monterrey to the Texas border near McAllen. Imported Mexican gas deliveries will begin January 1, 1980, at an initial price of $3.62/MCF. The price will be adjusted quarterly by the same percentage as the change in world crude oil prices (New York Times 1979). Although the amount of gas involved is minimal, U.S. gas distribution/transmission companies are hopeful that this initial agreement may lead the way to increased Mexican imports from the new natural gas finds in the Mexican Gulf.

Table 2-3. Imports of Natural Gas (MMCF) to the United States, 1955-1978[a]

Year	Total	Canada	Mexico	Algeria[b]
1955	10,892	10,885	7	0
1960	156,843	109,855	46,988	0
1965	456,694	404,687	52,007	0
1966	480,591	431,955	48,636	0
1967	564,228	513,256	50,972	0
1968	651,885	604,462	47,423	0
1969	726,952	680,107	46,845	0
1970	820,781	778,688	41,336	757
1971	934,547	910,925	20,689	2,933
1972	1,019,495	1,009,092	8,140	2,262
1973	1,032,903	1,027,216	1,632	4,055
1974	959,285	959,063	222	0
1975	953,007	948,114	0	4,893
1976	963,768	953,613	0	10,155
1977	1,010,431	996,723	2,384	11,324
1978	965,545	881,123	0	84,422

[a]Data from American Gas Association (1979c).

[b]Quantities represent total LNG imports to the United States.

Liquified Natural Gas

2.042
The application of liquified natural gas (LNG) technology has been utilized in the United States for more than three decades. The first terminal to import liquified gas from overseas for purposes of increasing total gas supply was completed in 1977 at Cove Point, Maryland. This facility, jointly owned by the Consolidated Natural Gas Company and the Columbia Gas System, provides an important source of natural gas to these utilities. Imported LNG increases the supply of gas availability to Consolidated by 15% above those available prior to the opening of Cove Point, and it represents the largest single increase in gas supply to the company since the completion of natural gas pipelines from southwest fields. The Cove Point plant has the capacity to deliver 1 BCF of natural gas a day. Two other LNG importing terminals are currently operating in the United States: Distrigas Corporation with a facility at Everett, Massachusetts; and Southern Energy Company, Elba Island, Georgia. In addition, a number of LNG receiving facilities are being planned or are under construction (Am. Gas Assoc. 1979e).

2.043
Liquified natural gas is currently providing an important source of natural gas supply to some U.S. gas utilities, and will be an increasingly important source of supply in future years. In 1978, approximately 84.4 BCF of LNG was imported into the United States (Table 2-3). According to the American Gas Association, if all the LNG projects currently planned are in full operation by 1990, about 1.5 TCF/year of LNG will be supplied to U.S. markets (Am. Gas Assoc. 1979e). The price paid for LNG is now and will probably remain significantly greater than the price of gas from domestic wells. The National Fuel Gas Distribution Company of New York currently sells 10.6 BCF annually of high-priced SNG/LNG at more than $4.20/MCF (Booz·Allen & Hammilton 1979).

Summary

2.044
Of the eight alternative natural gas supplies described in this section, only three appear to have the potential for near-term increased production comparable to the Reference Program. These are regional onland reserves, Outer Continental Shelf reserves in the Gulf of Mexico, and Alaskan reserves. These alternatives utilize existing technology on proven reserves, have sufficient regional infrastructure for increased development, and are or will be tied to the Lake Erie markets by existing transmission facilities. Development of these resources could provide an alternative to the Reference Program.

2.045
The other natural gas supplies appear to have serious deficiencies as alternatives to Lake Erie development. Tight sands, geopressurized aquifers, and coal seam methane gas could have increased production in the long term if advances in drilling and fracturing technology are realized and if increases in wellhead prices are large enough to compensate for higher production costs from these reserves. However, near-term production in the time frame of the Lake Erie Reference Program does not seem probable. Foreign imports are constrained by diplomatic relationship between the U.S. and country of origin of the gas. Imported gas is not expected to increase, and prices are expected to remain well above that of domestically produced natural gas.

2.046
Thus, the most probable alternative gas supplies for the Lake Erie region are accelerated development of regional onland reserves, development of the Outer Continental Shelf reserves in the Gulf of Mexico, and transport of Alaskan gas to the Midwest.

Alternatives That Extend Natural Gas Supplies

Low-Btu Coal Gasification

2.047
Natural gas supplies could be extended through the production of low-Btu gas. Commercially available technology to produce environmentally acceptable clean gas is available, but the end product is not yet cost competitive with conventional sources of natural gas.

2.048
Currently, there are only two commercially operated low-Btu gasification plants in operation in the United States. Several facilities are, however, in

the construction or planning stage (Bardos et al. 1978a). Because of the low heating values (less than 200 Btu/ft^3) of this energy source, a much larger volume (up to five times) of gas is required to equate to the heating value of natural gas. Also, utilization of low-Btu gas requires retrofitting and piping changes. Low-Btu gas is not interchangeable with pipeline quality natural gas.

2.049
At the present technological stage, the system appears to be best suited for small and specific types of end-users. Due to the volumes of gas needed, short transmission distances from gasification facility to end-users are necessary, and locations outside of metropolitan centers are desirable. There are no major problems meeting federal or state environmental standards in either the production (gasification facility) or combustion of low-Btu gas (Bardos et al. 1978a). Emission control systems are available to meet existing air emission standards. Because of the small size of the commercially available plants producing low-Btu gas, no significant environmental or socioeconomic problems are anticipated. The major problem associated with producing low-Btu gas is the cost of the end product due to the scale of production facilities and of emission control costs. It is estimated that a one billion Btu/day plant would cost $4-5 million. Depending upon the price of coal and level of emission controls, the price of low-Btu gas would range from about $2.50 to $3.60/million Btu (Bardos et al. 1978a).

Medium-Btu Coal Gasification

2.050
Medium-Btu gas is produced from the combustion of coal in the presence of steam and oxygen and has a heating value of 300-600 Btu/ft^3. Commercially available technology is available for producing environmentally acceptable gas for industry and utility markets. Although there are a number of medium-Btu gasification plants operating overseas, there are no commercially operating plants in the United States. Two commercial demonstration plants are currently being designed with U.S. Department of Energy (DOE) funding, but operation (if constructed) of a plant is not considered practical until the mid-1980s (Bardos et al. 1978b).

2.051
Since there is no experience base in the United States, estimates of costs to build and operate a medium-Btu gasification plant may not be currently accurate. It is estimated that the construction of a 75 billion Btu/day plant would cost about $200 million. In addition, in most cases an oxygen plant would have to be built in conjunction with the facility, thereby significantly increasing costs. Costs would also increase if more stringent air and water quality standards were imposed. Current estimates project that medium-Btu gas would cost $3.75 to $4.50/million Btu (Bardos et al. 1978b). Medium-Btu gas is not interchangeable with pipeline quality gas, and the additional costs of pipeline construction/transportation is a major consideration.

2.052
Because of the high capital cost requirements, medium-Btu gas would be best suited for very large industrial users or multiple energy intensive industries (industrial region). Large-scale electrical utilities are also potential end-users. The gas can be transported, thereby minimizing any site-specific

location problems, but the gas contains carbon monoxide and may arouse public opposition in any proposal to pipe it from gasification facility to end-user.

High-Btu Coal Gasification

2.053
High-Btu gasification involves the production of pipeline quality gas from coal. The process is similar to that in the production of low- or medium-Btu gas except that in a final step the methane concentration is increased (and thus the heating value). The main objective is to add hydrogen (via steam) to the carbon contained in coal, thereby producing methane (CH_4), the major constituent of high-Btu gas. Gas leaving the gasification phase has a heating value of approximately 250-450 Btu. In methanation, carbon dioxide, hydrogen sulfide, and other impurities are removed. The gas is methanated by reacting carbon monoxide and hydrogen (with a catalyst, generally nickel). This increases the heating value of the gas to pipeline quality, about 900-1000 Btu/ft^3 (Samsa et al. 1977).

2.054
At present, there are no commercial methanation plants in operation in the United States, although several pilot plants are under construction or are in the planning stage (Am. Gas Assoc. 1978d). Because of its similarity to natural gas, high-Btu gas can be distributed through existing pipelines and can compete for the same markets now being served by natural gas. Both industry and electrical utilities are potential large end-users of high-Btu gas.

2.055
High capital costs for the construction of a large-scale high-Btu gasification-methanation facility is viewed as a major barrier for commercial interest in this energy source. Projects in the construction or planning stages are generally built by a consortium of energy companies combined with government financing. The projected costs for a high-Btu facility currently being built in Mercer County, North Dakota, are \$890 million plus an additional \$88 million for transmission facilities (Am. Gas Assoc. 1978d). Projected costs for most high-Btu plants currently exceed \$1.3 billion (Am. Gas Assoc. 1978d; Gallo et al. 1978). An estimated price for high-Btu gas (the end product) at the plant, not including transmission and distribution costs, is \$5.60/MCF (Am. Gas Assoc. 1978d). The commercialization of high-Btu gas production supplying gas to national markets is not a short-range solution to the nation's natural gas supply situtation. Most plants now in the planning stage may not be fully operational until the late 1980s, and largescale production supplying significant volumes of gas to end-users may not be realized for decades.

Summary

2.056
None of the three coal gasification alternatives appears to be a reasonable alternative to the proposed action. Low-Btu gas is not a natural gas substitute, nor can it be easily transported long distances from its point of origin to the end-user, such as from the Appalachian coal deposits to the Lake Erie region. Medium-Btu gas would probably not be available in large quantities by the mid 1980s, and it could not be transported to the Lake Erie region along existing transportation systems. Although high-Btu gas could be shipped via existing pipelines from its point of origin to the Lake Erie region, high

costs of facility construction and high projected price for the fuel indicate that high-Btu gas is not a reasonable alternative to the proposed action in the near term.

Conservation, An Alternative That Reduces Demand

2.057
Nationwide, gas conservation within the residential sector resulted in a decrease in consumption, averaging about 10% per customer per degree day during the immediate "post-embargo period" (Am. Gas Assoc. 1978a). Gas conservation within the industrial sector has also led to significant reductions in natural gas demand (Myers and Nakamura 1978).

2.058
Reflecting national trends, natural gas conservation within the Lake Erie region has been a major factor in reducing gas demand. Conservation within the East Ohio Gas Company's service area has reduced natural gas demand in the residential and commercial sector by 12-15% since 1973 (East Ohio Gas Co. 1979--personal communication). Within Consolidated's market area, conservation has reduced residential and commercial demand by 14% from 1973 through 1978.* This has meant a loss in sales of about 39 BCF as a direct result of gas conservation from residential and commercial end-users (Consolidated Nat. Gas Co. 1979--personal communication).

2.059
Columbia Gas of Ohio has also reported that conservation measures have resulted in significant savings in gas consumption by end-users. Columbia Gas estimates that residential gas demand is down by 21% since 1973. Although this reduction is partially (about 2%) a result of customer losses, most of the decline is due to conservation (Columbia Gas of Ohio 1979--personal communication). Commercial usage of natural gas is down about 20% compared to the base year 1972-1973, and industrial demand has been reduced by about 34% during the same time period.

2.060
The immediate response by end-users to escalating gas prices has been to reduce consumption. This has been accomplished by a number of simple but effective conservation measures--lowering thermostats, insulation, etc. Projections by the gas distribution companies indicate that conservation will continue to be a major factor in reducing gas demand. Greater savings in gas use beyond the simple conservation measures, however, are expensive to accomplish and are often resisted by end-users. Construction of more energy-efficient houses and industrial and commercial buildings (design of the built environment) can reduce space-heat energy consumption, but at increased cost over construction of conventionally designed buildings. The installation of gas-efficient household utilities is also an effective conservation measure, but is expensive. In the industrial sector, new plants and equipment designed

*Consolidated's market area encompasses major portions of the states bordering Lake Erie and West Virginia. East Ohio Gas is a distribution company for Consolidated Natural Gas Company.

to reduce gas consumption are available, but the long life of existing capital stock may forestall continued and significant savings in industrial gas use.

2.061
In the short term, conservation will continue to reduce natural gas demand in the Lake Erie region as greater numbers of end-users employ inexpensive gas-saving measures. Even greater savings in gas use can be realized with investments in more energy-efficient houses, plants, and equipment; however, these investments are expensive and are longer-term conservation responses to rising natural gas prices.

DESCRIPTION OF THE ONLAND ALTERNATIVE PROGRAM

Regional Land-Based Resources

2.062
The stratigraphic sequences thought to contain natural gas reserves under Lake Erie are also present in the tier of counties bordering the U.S. shores of the Lake (Shafer 1977). Natural gas shows have been found in Devonian shales, Silurian dolomites, Silurian sandstones, and Cambrio-Ordovician dolomites. Gas production from Devonian shales has yielded about 3 TCF since the turn of the century and proved reserved are estimated at 1.1 TCF (Kuuskraa et al. 1978). The major problem associated with significant increases in Devonian shale production is the lack of adequate permeability. Some type of enhanced recovery system is needed to stimulate the flow of gas which is generally below that of conventional wells. Hydraulic fracturing has been used but improvements in technology (e.g., directional drilling) and applied research (remote sensing to detect surficial fracture patterns) are needed before significant increases in production can be realized. The U.S. Geological Survey has estimated a total in-place Devonian gas resource of 500-600 TCF (Am. Gas Assoc. 1978b). The Columbia Gas System, which has done considerable work on Devonian shale, estimates that about 285 TCF of natural gas may be recoverable in the Appalachian area using existing technology (Potential Gas Comm. 1979). Both the institutional infrastructure and the technology exists to significantly increase natural gas production from Devonian shale. The proximity of this resource to the Lake Erie region would minimize distribution costs and be market competitive with other conventional sources of natural gas supply.

2.063
The Silurian onland deposits have been developed in Ohio, Pennsylvania, and New York (Figure 1-8); "Project Penny," organized by Columbia Gas Transmission Corporation, proposes to develop fields in the "Medina Zone" (Silurian sandstones) in areas of Pennsylvania and New York adjacent to Lake Erie (Anon. 1979). Janssens (1973) concluded that, with respect to at least one of the Cambrio-Ordovician dolomites, "especially favorable areas for production are the two or three tiers of counties south of Lake Erie." Thus, it appears reasonable to assume that reserves of natural gas on land will continue to be developed. If exploration and development activities were accelerated, partial compensation for the absence of lake drilling might be achieved under a scenario of severe gas curtailments. It is not suggested that onland drilling is a substitute for offshore drilling or that a new onland drilling program of comparable size and economic feasibility to the Lake Erie program could be achieved.

Onland Alternative Study Region

2.064

The region defined for the onland natural gas development alternative is larger than the 10-county study area defined in the Reference Program. The 23-county area (Table 2-4) was chosen (1) to include a land area comparable to or larger than the lease area in the Lake, (2) to include land areas of similar geologic structure to the Lake, and (3) to include "Project Penny" counties in New York and Pennsylvania. In all other respects, the 23-county alternative study region is arbitrarily separated from surrounding counties, which also have histories as gas-producing regions. It is not suggested that onland natural gas development would be preferred in the Onland Alternative Study Region rather than in other areas, or that accelerated onland gas development

Table 2-4. Counties of the Onland Alternative Study Region

State	County
New York	Erie[a]
	Wyoming[b]
	Livingston[b]
	Allegany[b]
	Cattaraugus[b]
	Chautauqua[a,b]
Pennsylvania	McKean[b]
	Warren[b]
	Erie[a,b]
	Crawford[b]
	Venango[b]
	Mercer
Ohio	Ashtabula[a]
	Trumbull
	Lake[a]
	Geauga
	Portage
	Cuyahoga[a]
	Summit
	Medina
	Lorain[a]
	Huron
	Erie[a]

[a]Included in the Reference Program Study Region.

[b]Included in Project Penny.

is a feasible substitute for a Reference Program. Rather, the Onland Alternative Study Region is defined strictly for the purpose of making an environmental comparison to the Reference Program.

2.065
Onland gas development would be regulated by agencies of the 3 states and 23 counties in which development was occurring. Regulations applicable to gas drilling are not consistent within the study region, and permit or lease restrictions may change with changing regulatory environment. Therefore, it is difficult to describe exactly how onland natural gas development might proceed. Certain assumptions have had to be made based on current industry practice, and in many instances technological specifications are given as ranges of values meant to encompass the whole region. It should be recognized that specific state regulations may limit drilling activities to only a small portion of that range of values.

Onland Exploration

2.066
Exploration activities include geophysical surveys and exploratory well drilling. It is assumed that geophysical investigations would be accomplished by either thumping or by detonation of explosive devices. Exploratory wells are assumed to be drilled by a method comparable to developmental well drilling, except exploratory wells would be drilled to greater depth. The magnitude of exploratory activity necessary for additional onland development of a magnitude comparable to the Reference Program is not specified.

Onland Development

Location of Fields and Field Size

2.067
The onland alternative does not specify where development might occur within the study region. All areas will be considered potential drilling sites, although surely this would not actually be the case. The number of wells and timing of drilling necessary to meet either regional demands or to substitute for the Reference Program also will not be specified. Since many easily produced reserves have already been developed onland, production figures for the Reference Program are probably not valid predictors of production figures onland.

Well Spacing

2.068
It is assumed that an unspecified number of wells would be drilled somewhere within the Onland Alternative Study Region in well fields, with the following spacing.

New York

2.069

Wells would not be drilled closer than 660 ft from a lease boundary line or closer than 1320 ft from either another producing well or a well being drilled in the same pool.

Pennsylvania

2.070

Well spacing would depend upon the geological characteristics of the producing formation and would be specified on the drilling permit issued by the state. Wells would not be drilled within 330 ft of the lease boundary line.

Ohio

2.071

Wells 2000-4000 ft deep would not be drilled closer than 600 ft from another well or closer than 300 ft from a tract boundary. Minimum spacing would be one well per 20 acres. Wells deeper than 4000 ft would not be drilled closer than 1000 ft from any producing well. Minimum spacing would be one well per 20 acres.

Well Depth

2.072

Estimated depth to producing formations are given in Table 2-5. These are rough approximations based on a dip to the southeast of the Lake Erie axis of gas-bearing Silurian formations and on the elevation of the county seat. Actual depth to formation at a specific site can be expected to vary from these figures. However, it is necessary to estimate depths to estimate other parts of the Onland Alternative Program.

Site Preparation

2.073

It is assumed that an area of 3 acres at each well would be required for drilling activities, including turn-arounds, storage areas, and pits. Access to the drilling site would be described in the lease and consist of a graded dirt road 16-24 ft wide, unless wet soil conditions required application of gravel. The site would be cleared of tall vegetation; in hilly areas, the site would be graded to approximately level conditions. Topsoil would be removed and piled to one side. Gravel would not be applied to the site unless soils were too unstable to support drilling equipment and truck traffic. The pit would be constructed large enough to contain wellbore volume, plus a 50% excess. In Ohio, the pit would be lined. Regulations and practice on control of pit seepage vary by state and locality. State-of-the-art construction techniques will be used to minimize erosion problems.

2.074

A surface hole (20-50 ft deep, 20-30 inches in diameter) would be drilled and cased with an unspecified diameter pipe. Cuttings generated might be from 4 to 25 tons. Four to 10 bbl of drilling muds and 36,000 to 90,000 gal of water would be used. Fifteen to 30 sacks of cement would be used to cement the surface casing.

2.075

A wood- or cement-lined cellar, 6 x 6 x 4 ft, would be dug around the surface hole pipe to contain minor surface spills. If regulations allow onsite disposal of refuse, garbage pits would be dug; if continuous onsite occupancy was necessary, cesspits might be required.

Table 2-5. Estimated Depth of Well to Clinton Formation[a] for the Onland Alternative Program

County	Depth (ft)
New York	
Erie	2400
Wyoming	3100
Livingston	2600
Allegany	3200
Cattaraugus	4600
Chautauqua	4200
Pennsylvania	
Erie	3500
McKean	5300
Warren	5500
Crawford	5500
Venango	6600
Mercer	6800
Ohio	
Ashtabula	3900
Trumbull	5900
Portage	5300
Summit	4800
Cuyahoga	3800
Medina	4000
Lorain	3600
Huron	3500
Erie	3000
Lake	2800
Geauga	2800

[a]Depths for the Lockport Formation would be 200 ft less.

Water Supply

2.076
If the drill site is within 0.5 mile of a lake, pond, or stream, water would be pumped to the site by a 4-6 inch surface pipe. If the drill site is within a 30-min round trip of a water supply, water would be hauled by truck and stored onsite (500-1000 bbl capacity storage). If water supplies are farther than a 30-min round trip, a service water well would be dug with a small truck-mounted rig. Such a well could supply several drilling sites in one gas field.

2.077
Power to the site would be supplied by a generator on the drilling rig, which would use 500-600 gal/day of diesel fuel.

Drilling and Well Completion

2.078
The drilling rig would be brought to the site by trucks which are assumed to conform to state and federal axle load limits. Conventional roads should be adequate over much of the Onland Alternative Study Region. Some bridge work might be necessary if bridges with low weight limits could not be circumvented. Truck turn-around areas and equipment laydown areas (included in the specification of a 3-acre site) would be required to set up the rig at the drill site.

2.079
It is assumed for comparison to the Reference Program that the rigs used for drilling would be rotary rigs with a 7000-ft rating using 3.5-inch drill pipe.

2.080
The rig will be trucked to the site in several pieces, with the largest section being the mast. The rig includes a storage shed, pipe racks, drill pipe, drill collars, pumps, engines, doghouse, and mud tanks. The rig will be fitted with API Series 900 (3000 psi) BOP equipment.

2.081
A surface hole will be drilled inside the 20- to 30-inch hole, below all known aquifers, and cased. Then drilling would proceed to total depth, which is assumed to be that given in Table 2-5 for the county in which the well is located. Drilling rate would be approximately 600 ft/day. Drilling would be closed-cycle, with mud circulated from the well to the mud tanks and cuttings channeled to the pit. It is assumed that 120 lb or 1.2 ft^3 of cuttings would be generated for each foot of drilling depth. To the extent that rig crews come to a local community from outside, additional contributions to wastewater loading on municipal sewage treatment facilities is assumed to be 200 gal/worker for 25 workers. Sanitary facilities at the rig site are assumed to be self-contained units provided by a private contractor who disposes of wastes in a nearby municipal sewage treatment facility. Garbage is assumed to be generated at a rate of 5 lb/worker/day and general rig trash is assumed to be 10 lb/day. Both are disposed of by burning or pit burial, unless either is prohibited by local or state regulations, in which case they will be carted to local landfills. Oily wastes from engine maintenance will be either burned or disposed of in approved landfills.

2.082
Drill stem tests will be performed as specified in the Reference Program except that gas will be flared away from the rig. Liquid returns will be run into the pit. A success ratio comparable to reports of "Project Penny" (69%) (Anon. 1979) will be assumed.

2.083
Cement plugs at depth would be set (see Table 1-22), the casing would be cut off 10 to 50 ft below the surface, and the surface cement plug would be set. Pits would be filled in, leaving pit contents in place, except in Ohio, where

pit contents would be disposed of in approved landfills. The rig would be dismantled and moved to another location. The site would be returned to the condition specified in the lease. It is assumed that the site would be returned to approximately original contours and that any topsoil removed during site preparation would be returned.

2.084
Production casing would be run into the hole and cemented (see Table 1-22). Completion fluid would be circulated through the hole. Acid would be spotted across zones to be perforated. The blowout prevention equipment would then be removed and the wellhead attached. If necessary, the well would be swabbed down at least to 450 ft. The lubricator would be attached to the wellhead and the well perforated. The lubricator would then be removed. The rig would be dismantled and moved to another location. The flowline would then be attached and flow tests run to determine if the well should be stimulated.

2.085
Total time from beginning of construction to completion is assumed to be the same as for the Reference Program, except one-day drilling time would be necessary for each 600 ft additional well depth. A maximum of 500 wells could be drilled in a year with 25 rigs (15-day interval between wells, 300-day drilling season). Actual rates would probably be less.

2.086
When completed, a fence 20 x 20 ft would be placed around the wellhead and the rest of the site would be returned to the condition specified in the lease. This condition is assumed to approximate original surface contours with top-soil replaced. Other arrangements may be specified by the agreement between lessor and lessee.

Stimulating the Well

2.087
Well stimulation would follow the procedure specified in the Reference Program, except stimulation equipment would arrive by truck, not barge. Stimulation returns would be run into the pit, without separation, for 12 hours. After 12 hours, well flows would be run into a test separator or the flowline would be reattached.

Pipelines

2.088
Configurations of flowlines and gathering lines would depend on well configuration and field location, both unspecified in the Onland Alternative Program. Lines are assumed to be buried below the frostline (4-6 ft deep) with a backhoe or ditch-digging machine. Rights-of-way are assumed to be between 10 and 30 ft wide. At stream crossings, the lines would be buried (small streams) or suspended overhead (rivers). State-of-the-art construction techniques will be used to minimize erosion problems. Maintenance of pipeline right-of-way is assumed to include periodic herbicide application to control woody growth. It is assumed that no new main transmission pipelines would be necessary.

Production

2.089
It is assumed that production facilities would be of the type described in the Reference Program. If possible, existing facilities would be used. Production might begin, at the earliest, one year from the beginning of drilling activity. If petroleum is encountered in onland wells, it would be produced along with the natural gas.

Abandoning Producing Wells

2.090
When gas returns from the wells diminish to a point below economic profitability, the wells would be abandoned. Procedures for abandonment have already been described for dry wells, except cement plugs would be placed above and below the producing formations in production wells and the wells would be marked according to state regulations.

COMPARISON OF ALTERNATIVES

Regional Land-Based Resources

2.091
In this section, the Onland Alternative Program is compared with the Reference Program on the basis of frequency, duration, and magnitude of impacts to regional environments. The conclusions about the consequences result from the analysis of consequences presented in Chapter Four. Since neither site-specific environmental descriptions nor site-specific engineering plans are available for the Reference Program or the Onland Alternative Program and since neither suggested program is an industry development proposal, a detailed quantitative comparison of consequences is not possible. Therefore, qualitative comparisons are developed based on whether (1) the consequence of an alternative are perceived to be greater than, equal to, or less than the consequences of the Reference Program; (2) the consequences of an alternative are similar or different to the consequences of the Reference Program, or (3) the consequences are indeterminate. The comparisons are independent of regional value systems.

2.092
Regional natural gas resources include both conventional reserves from the Medina and Lockport formations and nonconventional reserves from Devonian shales. Either of these two reserves could be produced by the Onland Alternative Program. Since the technological development of Devonian shale production is not yet complete, the consequences of developing and producing this reserve are assumed to be similar to those of developing and producing conventional reserves. Assumptions about how conventional onland reserves would be developed and produced were outlined above in the description of the Onland Alternative Program.

2.093
The comparison between the Reference Program and the Onland Alternative Program is presented in Table 2-6. Because 10 pipeline landfalls would be constructed along the U.S. Lake Erie shoreline, the Reference Program would have greater consequences to shoreline geology and erosion than the Onland

Table 2-6. Summary Comparison of the Reference Program with the Onland Alternative Program

Impact Categories	Impacts of the Reference Program	Impacts of the Onland Alternative Program	Environmental Consequences
Shoreline geology and erosion	10 pipeline landfalls causing disturbance and erosion due to pipeline construction, maintenance, and decommissioning. Adverse impacts minor, magnitude dependent on location and construction practices.	No shoreline activities anticipated.	Reference Program has greater consequences.
Groundwater hydrology	Limited, localized degradation of water quality in aquifers beneath the Lake. Negligible degradation of shallow onland aquifers along pipeline corridors.	Adverse impacts to shallow and deep aquifers more frequent and of greater severity than the Reference Program by several orders of magnitude, in part because of domestic use.	Onland Alternative Program has greater consequences.
Water quality (Surface)	Minor adverse impacts from sediment resuspension, temporary and localized impacts from liquid hydrocarbons and calcium chloride due to accidents of very low frequency and short duration.	Minor, temporary, localized adverse impacts to surface waters from accidental release of hydrocarbons. Magnitude dependent on drilling locality.	Consequences similar.
Aquatic ecology	Temporary local adverse impacts from sediment resuspension to plankton, benthos, and fish. No adverse impacts from resuspended contaminants. Localized, minor adverse impacts to plankton from effluents. Localized, temporary disturbance of macrophytes from nearshore pipeline trenching. Local adverse impacts on plankton, benthos, and fish from accidents.	Adverse impacts expected to plankton, benthos, and fish from water withdrawal, erosion, materials used in drilling, and accidental release of fluids. Adverse impacts minor to significant depending on drilling locality, sensitivity of local biota, and drilling practices.	Consequences similar.
Water use	Temporary, slight adverse impacts to recreational use of beach and Lake near landfalls. No detectable impacts to Lake Erie fisheries. Beneficial impacts to ports, minor negative impacts to shipping and navigation. No adverse impacts predicted to municipal or industrial water supplies or treatment facilities. Inadequate information to determine whether di- or triethylene glycol from a pipeline break would impact potable water use.	Temporary impacts to recreational water use if rigs located near surface water bodies. No commercial fishing operations expected in water bodies affected. No ports utilized for onland drilling.	Consequences different, but neither clearly greater than the other.
Terrestrial ecology	Impacts from 10 pipeline landfalls and gas production facilities dependent on site-specific characteristics.	Magnitude and frequency of impacts an order of magnitude greater than for lake drilling. Type and magnitude of impacts dependent on location of drilling and production activities.	Onland Alternative Program has greater consequences.

Table 2-6. Continued

Impact Categories	Impacts of the Reference Program	Impacts of the Onland Alternative Program	Environmental Consequences
Endangered species	Possible adverse direct effects on fish and minute incremental destruction of eagle and other bird habitat. Magnitude of effects dependent on activity location.	Highly probable adverse direct effects on some birds, plants, fishes, amphibians, reptiles, and mammals. Incremental destruction of habitat, frequency and magnitude of effects dependent on site-specific characteristics.	Consequences similar, but insufficient information to compare magnitude.
Land use	Adverse impacts expected from construction and operation of 10 pipeline landfalls and 10 production facilities. Magnitude and type of impact dependent on site-specific land-use characteristics and plans. Adverse impacts from onshore disposal of drilling wastes.	Adverse impacts expected from siting rigs, access roads, and pipelines, and from production facilities. Type, frequency, and magnitude of impacts dependent on site-specific land-use characteristics and plans, but greater than Reference Program.	Consequences different, but neither clearly greater than the other.
Air quality	Local, minor, temporary adverse impacts from diesel engine emissions, well stimulation and testing, accidents, and gas production.	Local, minor and temporary adverse impacts from particulates as well as diesel engine emissions, well stimulation and testing, accidents, and gas production. Magnitude of impacts dependent in part on site-specific characteristics. Proximity of drilling and production to vegetation and people increases consequences of adverse impacts compared to Reference Program.	Onland Alternative Program consequences greater.
Esthetic impacts	Local, temporary adverse impacts expected along the lakefront. Permanent adverse impacts at production facility sites negligible or large, depending on site-specific characteristics.	Temporary and permanent adverse impacts at drilling sites, pipelines, and production facilities. Frequency and duration of impacts much greater than Reference Program. Magnitude of impacts dependent on site-specific characteristics.	Onland Alternative Program consequences greater.
Cultural resources	Adverse impacts expected, frequency and magnitude dependent on site-specific characteristics.	Adverse impacts expected, frequency and magnitude dependent on site-specific characteristics.	Insufficient information to make conclusions.
Demography	Negligible impacts.	Negligible impacts.	Consequences similar.
Economy	Beneficial impacts to industrial gas consumers in the area and protection from gas curtailments.	Beneficial impacts to industrial gas consumers in the area, and protection from gas curtailments.	Consequences similar.

Alternative Program. The Reference Program would not generate greater adverse environmental consequences than the Onland Alternative Program for any other categories of impacts.

2.094
Consequences of the two programs are either similar (of the same type and relative magnitude) or not clearly different (different types but similar overall) in magnitude for the impact categories of water quality, water use, aquatic ecology, land use, demography, and socioeconomics. Water quality, water use, and aquatic ecology impacts of the two programs are of similar types, but the location of the environment sustaining the impacts differs. The Reference Program would have the majority of its aquatic effects on Lake Erie, whereas the Onland Alternative Program would have effects on the rivers, streams, and reservoirs of the Onland Alternative Study Region. Both Lake Erie and other regional surface waters are highly important regional resources.

2.095
Land-use impacts from the two programs are not of a similar type. Location of onland drilling activities would produce land-use conflicts of greater frequency, magnitude, and duration than the Reference Program. However, the Reference Program specifies onland disposal of drill cuttings, drilling fluids, and other effluents in landfills that are a very limited resource. The use of landfills created for disposal of hazardous or industrial waste by-products of the Reference Program would be a serious adverse environmental consequence due to competition with other industries for landfill space.

2.096
No difference is perceived in the regional socioeconomics and demographic effects of the two programs. Impacts, both beneficial and adverse, would be of the same type and magnitude.

2.097
The Onland Alternative Program has greater adverse environmental consequences for the impact categories of groundwater hydrology, terrestrial ecology, air quality, and esthetics. The differences are due to the proximity of onland drilling activities to human habitation and vegetation or to greater frequency and magnitude of impacts in the Onland Alternative Program.

2.098
In conclusion, the choice of the Onland Alternative Program would not reduce overall environmental consequences to the Lake Erie region from natural gas development. The elimination of minor, local increases in shoreline erosion would be more than offset by greater impacts to groundwater hydrology, terrestrial ecology, air quality, and esthetic quality from onland gas development.

Domestic Conventional Reserves

2.099
Two natural gas reserves are being developed which are potential substitutes for gas produced from the Reference Program. Alaskan gas will reach the Midwest by the mid-1980s when the Alaskan Natural Gas Transportation System will be completed (Federal Power Commission 1977). Natural gas from OCS reserves developed in the mid-1980s in the Gulf of Mexico could be transported through existing transmission systems. The environmental impacts of oil and

gas development both in the Gulf of Mexico and Alaska are summarized in Table 2-7.

2.100
In order to compare the environmental consequences of the two alternatives with the environmental consequences of the Reference Program, some proportion of the impacts of the alternative programs must be assigned to the substitution of alternative natural gas supplies for the natural gas produced from the Reference Program. It is unreasonable to ascribe all impacts from the alternative programs to the use of this gas to substitute for the Reference Program because Alaskan and Gulf of Mexico reserves will be developed regardless of the final decision on whether Lake Erie natural gas development should be allowed. Also the alternative resources are being developed to produce crude oil in addition to natural gas, and it is not clear that the rate of development of the alternative resources is dependent on the demand for natural gas. Conversely, it is unreasonable to ascribe none of the consequences of Gulf of Mexico and Alaskan gas development to the use of either of the natural gas resources to substitute for the Reference Program, since the environmental consequences sustained by Alaska and the Gulf of Mexico are the result of demand for gas in energy-deficient areas of the country such as the Lake Erie region.

2.101
The portion of consequences of oil and gas development in Alaska and the Gulf of Mexico that should be assigned to the substitution of these resources for Lake Erie natural gas depends upon the way in which the alternative supplies enter the transmission systems. Alaskan gas reaching the Midwest through the Alaskan Natural Gas Transportation System will have transport rates of 2.6 BCF/day. At a time when Prudhoe Bay production will be diminishing (1990), Beaufort Bay production will be increasing (U.S. Bur. Land Manage. 1979c). Additional demand by the Lake Erie region might result either in increased total production from the Beaufort Sea reserves or in a redistribution of quantities delivered to different terminals of the transportation system, depending upon the state of the natural gas market and the limits of transportation rates set by the capacity of the pipeline. At peak production during a 360-day year, the Reference Program would produce about 80 BCF in 1990, equal to about one month's total deliveries through the Alaskan Natural Gas Transportation System.

2.102
In the Gulf of Mexico, production from OCS Lease Sales 58A, 62, and A62 would reach full production by 1990 (U.S. Bur. Land Manage. 1979a,b,c). This gas would be transported to onshore production and transmission facilities in Texas, Louisiana, Alabama, Mississippi, and Florida. Production is expected to be 0.3 to 0.8 BCF/day. Reference Program production in 1990 would be equivalent to 100 to 267 days production from these three Gulf of Mexico lease areas.

2.103
In conclusion, some portion of the impacts from gas and oil production in the Gulf of Mexico and the Beaufort Sea, Alaska, should be ascribed to the use of these alternative supplies as substitutes for production from the Reference

Table 2-7. Impacts of Oil and Gas Development of Outer Continental Reserves in the Gulf of Mexico and Alaska[a]

Impact Category	Outer Continental Shelf: Gulf of Mexico	Outer Continental Shelf: Beaufort Sea, Alaska
Shoreline geology and erosion	Adverse impacts expected at pipeline landfalls.	Adverse impacts from dredging, island and causeway construction, and pipeline landfalls.
Groundwater hydrology	None.	None.
Water quality	Small adverse impacts expected from dredging and pipeline construction and from discharge to marine waters of drill cuttings, drilling fluids, rig wastes, and formation waters with dissolved and entrained hydrocarbons (including oil). Moderate to severe adverse impacts in the event of an accidental uncontrolled release of oil from rigs or wellheads.	Some adverse impacts expected from dredging and pipeline construction and from discharge to marine waters of drill cuttings, drilling fluids, rig wastes, and formation waters with dissolved and entrained hydrocarbons (including oil). Moderate to severe adverse impacts in the event of an accidental uncontrolled release of oil from rigs or wellheads.
Aquatic ecology	Local, temporary adverse impacts to aquatic biota in areas receiving discharges from the drilling rigs. High probability of severe adverse impact in areas contaminated by oil from accidental loss of well control (low probability event).	Local, temporary adverse impacts to aquatic biota in areas receiving discharge from drilling rigs. Habitat destruction from construction of onshore facilities and dredge-fill operations. Adverse impacts expected to marine birds and mammals from chronic oil releases. High possibility of severe adverse impact in areas contaminated by oil from accidental loss of well control (low probability event).
Water use	Minor adverse impacts to recreation from chronic oil discharges, and moderate to severe impacts to recreation from large accidental oil spills. Two hectares sea bottom removed from fishing grounds for each successful well. Obstructions to trawling activities from pipelines, wellheads, and debris.	Impacts to subsistence hunting and fishing activities of Native American residents.
Terrestrial ecology	Adverse impacts to estuarine marsh habitats in the event of a major spill. Magnitude dependent upon location.	Habitat destruction and degradation to tundra and wetlands from onland activities. Adverse impacts from acute and chronic oil spills. Reduction in wildlife expected.

Table 2-7. Continued

Impact Category	Outer Continental Shelf: Gulf of Mexico	Outer Continental Shelf: Beaufort Sea, Alaska
Endangered species	Impacts are possible, but unlikely.	Possible significant or severe impacts on bowhead whale and gray whale populations.
Land use	Corridor 30-50 ft wide at pipeline landfalls.	Onland activities would be adjacent to Prudhoe Bay industrial enclave. Some incremental increase in conflicts with Native American subsistence activities. Degradation of wilderness values in areas with no previous history of development.
Air quality	Local, temporary degradation of air quality in the immediate vicinity of offshore operations.	Local, temporary degradation of air quality from facility operation, gas release, and volatilization of light ends from oil spills.
Esthetic impacts	Minor adverse impacts in the immediate vicinity of drilling operations and production facilities.	Adverse impacts expected in areas without other development. Incremental impacts in other areas.
Cultural resources	Small chance that activities of the program will disturb undetected cultural resources.	Major impacts to Native American subsistence patterns. Possible impacts from development on historical and archeological resources.
Demography	Project represents a continuation of existing employment patterns.	Development of the Beaufort Sea would extend industrial activity beyond the time of Prudhoe Bay development phases, partially stabilizing demographic trends and their sociological impacts.
Economy	Project represents a continuation of existing economic structures of the region.	Insignificant number of additional jobs created by project; proposal will add about 2% to all indications of economic growth and activity.

[a] Data from U.S. Bureau of Land Management (1974, 1979a-d).

Program. The major differences between these alternatives and the Reference Program are:

1. The production of oil as well as gas from high-pressure formations in the alternative reserves greatly increases the chance of significant oil contamination in the Gulf of Mexico and the Beaufort Sea.

2. Impacts predicted for the alternatives in the Gulf of Mexico and the Beaufort Sea are orders of magnitude greater than the impacts predicted for the Reference Program.

3. Beneficial impacts to ports and to the regional economy in the Lake Erie region would be lost or postponed if either or both of the alternatives were adopted.

4. Adoption of either or both of the alternatives would eliminate the adverse consequences of the Reference Program to the Lake Erie region.

Alternatives That Reduce Demand

2.104
If Lake Erie natural gas reserves were not developed, some or all of the excess regional demand might eventually be met by conservation practices initiated by domestic or industrial end-users because of rising gas prices, public perception of gas shortages, changes in priorities of expenditures of personal or corporate funds, or adoption of alternative forms of energy. In this case, all the adverse environmental impacts of Lake Erie development would be postponed until such time as the demand for Lake Erie natural gas would necessitate its development. Beneficial impacts of the Reference Program would also be postponed.

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CHAPTER THREE: ENVIRONMENTAL SETTING

3.001
Chapter Three provides the environmental setting necessary for discussing consequences (Chapter Four) of the Reference Program and the Onland Alternative Program.

SHORELINE GEOLOGY AND EROSION

3.002
The following discussions of shoreline features and characteristics, although specific to the Ohio portion of the Lake Erie shoreline, can generally be extended to the entire Reference Program Study Region. Bedrock underlying the lakeshore is relatively nonresistant Upper Devonian black and gray shales, with some siltstone. Low to high bluffs extend along almost the entire shoreline with only a few low-lying areas interrupting the bluff line. The shoreline is generally irregular where bedrock is exposed and smooth where unconsolidated materials are present. Irregularities in bedrock-formed shoreline are attributed to the presence of folds, joints or minor faults. The vertical sequence of deposits exposed in the bluffs (bottom to top) is as follows: shale (with some siltstone), till, and fine-grained lake deposits. In some shoreline areas, only the upper two units are visible above the water level. Erosion of exposed bedrock (and/or till) provides rock fragments that form coarse rocky beaches in some shoreline recesses. Small, sparsely distributed sand and gravel beaches also are accumulating at the toes of bluffs. These small beach areas tend to be larger along the eastern shoreline (Pincus 1960).

3.003
Landward of the shoreline, the land surface is an expression of till (primarily) and veneers of lake bottom sediments (where not removed by erosion). Some inland deposits of older, higher lake stages form sandy ridges parallel to the present shoreline.

3.004
Erosion and flooding of shorelands constitute major hazards in many reaches of the Lake Erie shoreline. It has been estimated that the existing shore strip in flood or erosion prone areas could be eroded within 30 years (Great Lakes Basin Comm. 1975d). The 30-year erosion zone is analagous to the floodplain management criteria in that areas are designated wherein structures should be prohibited or strictly regulated. Erodibility of the shoreline varies with the physical characteristics (topography, lithology, slope, etc.) of the shorelands. Locations of various shore types identified along the U.S. Lake Erie shoreline are indicated in Figure 1-13. Shore types consisting of clays, sands and gravels are classified as erodible, those of bedrock (hard shales) are generally considered nonerodible. Principal erosion processes acting on the shore are wave erosion and mass wasting (block falls, landslides, and sloughing of undercut slopes) (Carter and McPherson 1977). Of these two, wave erosion is the most significant.

3.005
Studies of changes along the Ohio shoreline (Carter and McPherson 1977) indicate that the effects of wave erosion and mass wasting have been altered by manmade erosion protection structures built along the shore. These structures decrease shoreline recession rates along and updrift of protected stretches

and increase recession rates along downdrift stretches. The overall trend, however, has been one of reducing shoreline recession rates.

GROUNDWATER HYDROLOGY

3.006
Although the Great Lakes Basin has some of the most productive aquifers in the United States, the Lake Erie Basin has the least overall groundwater potential due to the absence of deep freshwater aquifers (Great Lakes Basin Comm. 1975a). Aquifers in the Lake Erie region occur in unconsolidated sediments and in near-surface bedrock formations. The availability of groundwater in these aquifers varies from one area to another and is dependent on the numbers and types of aquifers, geologic structure, topography, and climate.

3.007
Under natural conditions, groundwater is always in motion from point of recharge to point of discharge or decreasing pressure (head). Ultimate discharge points are springs or rivers that drain the area, or pumping wells. Along the lake plain, the ultimate point of discharge is Lake Erie. South of the lake plain, the points of discharge are numerous, generally south-flowing streams and rivers.

3.008
In relation to the lithological and chemical character of the rocks, several distinct types of aquifers are recognized in the Lake Erie region. Sand and gravel formations are generally excellent aquifers because of high porosity and permeability. Coarse-grained alluvial and glacial deposits in valleys and adjacent to rivers and streams (when in hydraulic connection with surface-water bodies) can yield large quantities of water.

3.009
Consolidated sedimentary rocks (sandstones, siltstones, and shales) have little intergranular porosity; however, groundwater is contained in interconnecting bedding planes, fractures, and joints within the rock. Studies have shown that in consolidated rock, such water-yielding features are most common in the upper few hundred feet of the aquifer.

3.010
As a result of the clayey nature of the soil and the underlying glacial deposits in most of the region, infiltration of precipitation and groundwater recharge are very low. It should be noted that although groundwater recharge appears to be very low, considerable reserves of groundwater exist in the region, particularly in upland areas south of the Lake. Sand and gravel in buried valleys store large quantities of water which is replenished by slow recharge through overlying fine-grained deposits of glacial till.

3.011
Background information on aquifers that could be affected by Reference Program and Onland Alternative Program activities is presented according to geologic units in Table 3-1. The generalized geologic column--including thickness, lithologic description, water-yielding properties, and water quality--is presented for each formation.

Table 3-1. General Stratigraphy and Major Aquifer Systems in the Reference Program Study Region

Era	System or Series	Group or Formation	Lithologic Description	Thickness (m)	Yield (L/s)	Water-Bearing Characteristics and Water Quality	Remarks
			NORTH CENTRAL OHIO				
Cenozoic	Quaternary		Sand, gravel in drift	10-400	3.2-95	Water supplies are relatively adequate. Water from carbonate aquifers is very hard and highly mineralized. Glacial aquifers are less mineralized. Iron is often excessive in most aquifers. In the Silurian carbonate, aquifer sulfate content increases with depth.	Some local areas of carbonate aquifers have objectionable amounts of hydrogen sulfide. In areas where thin glacial deposits overlie porous limestone, groundwater contamination potential is high.
Paleozoic	Mississippian	Cuyahoga Group	Shale and sandstone	0-20	0-1.3		
		Berea	Sandstone		2.0		
		Bedford					
	Devonian	Ohio (Antrim)	Shales	0-500(?)			
		Olentangy					
		Delaware	Limestone				
		Columbus	Carbonates	0-200	0-12.6		
	Silurian	Raisin River	Carbonates	0-400	0-25		
		Tymochtee	Dolomite, salt, and gypsum				
		Greenfield	Dolomite				
		Lockport	Carbonates	150-230	9.5-14.5		
			NORTHEASTERN OHIO				
Cenozoic	Quaternary		Sand, gravel in drift	0-400	3.2-95	Many of the aquifers in this region are characterized as low-yielding. The chemical quality of water from the Sharon Formation is fair, although high iron and hardness are common. Berea water is of poor quality, very hard, and usually requires softening;, sulfate, chloride, and iron content are high in some areas. Mineral content in shallow bedrock aquifers causes problems. Salinity increases to the south. Iron and manganese are particularly troublesome.	The abundant shale formations limit the occurrence of bedrock aquifers and glacial deposits are generally low permeable clay-rich till. A better source of good quality water with large yields can be obtained from unconsolidated sand and gravel aquifers. The Upper Cuyahoga watershed has a high groundwater potential. Salt water leakage from oil and gas test holes has affected near surface aquifers in isolated areas.
Paleozoic	Pennsylvanian	Sharon	Sandstone and conglomerate	0-100	3.2-6.3		
	Mississippian	Cuyahoga	Shale and sandstone	0-180			
		Berea	Sandstone	0-235	3.2 6.3		
		Bedford	Shale; semiconfining bed	0-50			
		Cussewago	Sandstone	0-30			

Table 3-1. Continued

Era	System or Series	Group or Formation	Lithologic Description	Thickness (m)	Yield (L/s)	Water-Bearing Characteristics and Water Quality	Remarks
			NORTHWESTERN PENNSYLVANIA				
Cenozoic	Quaternary	Alluvium	Thin deposits of clay silt with thin beds of sand and fine gravel	0–5	0	Of no importance as source of water.	
		Ground Moraine	Unstratified, heterogeneous deposits of clay, silt, sand, and gravel (till)	0–60	0–0.3	Sand and gravel lenses in clay till.	Oil and gas seeps are common in Pennsylvania, especially near Lake Erie. This suggests that there are no fresh-water bedrock aquifers near the Lake.
		Terminal Moraine					
		Kames and Outwash	Stratified sand and gravel deposit	0–150	15–130	Most important aquifer in region. Stratified sand and gravel in river valleys (including buried valleys).	
		Lake Deposits	Stratified sand, silt, and clay; beach deposits contain coarse sand and gravel beds	0–20	0.3–20	Lake deposits are generally not water bearing. Beach sands may yield moderate supplies.	
Paleozoic	Pennsylvanian	Pottsville Formation (Sharon Formation)	Light to dark gray, fine-grained to coarsely conglomeratic sandstone with beds of gray shale, siltstone, limestone, and coal	10–100	0	Of no importance as aquifer (mostly unsaturated). Caps Pocono sandstones and shales in southern Crawford County.	
	Mississippian	Meadville Shale	Bluish-gray to ashen-gray shale alternating with thin sandstone beds	30	0	Generally not water-bearing.	Many potable ground-water sources have reportedly been contaminated by salt water and oil leaking from gas test holes. Shallow saline water is present locally in Pennsylvania. However, individual domestic wells can obtain potable water from shallow aquifers throughout this area.
		Sharpsville Sandstone	Thin, hard, limey gray-brown to tan-gray fine-grained sandstone alternating with shales	5–15	0.1–8	Sandstone beds yield an average of one L/s to wells.	
		Orangeville Shale	Soft, fissible dark blue to tan-gray shale	25	0	Generally not water-bearing.	
		Berea Sandstone	Tan, light gray or white, medium to fine-grained quartz sandstone	7–10	2	Important aquifer in Crawford County; yields are highest where sandstone is thickest. Water quality of the Berea is generally good, but hard to very hard with occasional high iron content.	
		Bedford Shale	Soft, blue-gray shale with calcareous sandstone beds in places	15	0–0.3	Generally not water bearing; sandstone beds may yield small amounts of water to wells.	
		Cussewago Sandstone (White Sand)	Soft, greenish-yellow to greenish-brown, quartz sandstone	10–25	1–6	Important aquifer in Crawford County. Cussewago water quality is assumed similar to that of the Berea Formation (generally good but hard and high in iron).	

Table 3-1. Continued

Era	System or Series	Group or Formation	Lithologic Description	Thickness (m)	Yield (L/s)	Water-Bearing Characteristics and Water Quality	Remarks
			NORTHWESTERN PENNSYLVANIA (cont'd)				
Paleozoic (cont'd)	Upper Devonian	Ohio Shale or Chagrin Shale (Riceville Formation in Pennsylvania)	Soft, nonresistant gray to black or blue fissile shale with minor sand lenses	30-300	<0.3	Potable water can be found near the till/shale contact--however, at greater depth, these shales contain saline water in most areas.	
		Woodcock Sandstone (First Sand)		6		First and second sands missing northwest of Meadville. Third sand is silty and poor aquifer. Shales generally not water-bearing.	
		Saegertown Shale	Coarse-grained grayish white sandstone beds separated by thick beds of shale	30	<1		
		Salamanca Sandstone (Second Sand)		6			
		Amity Shale		40			
		LeBoeuf Sandstone (Third Sand)		7-10			
		Chemung or Elk Creek Sandstone	Alternating shales and sandstones, fine-grained; gray, fossiliferous	100	<1	Generally not water-bearing; sandstone beds may yield small amounts of water to wells.	
		Girard Shale	Ashen-gray, uniform textured shale	20-70			
		Canadaway Formation (N.E. Shale)	Alternating gray shales and thin beds of fine-grained gray sandstone	90-150	<1		
			WESTERN NEW YORK				
Cenozoic	Quaternary	Pleistocene	Sand, gravel in drift	0-600	3.2-88	Water quality of the carbonate aquifers is fair to poor. The water is extremely hard and contains a high amount of dissolved solids. Sulfate content increases with depth in some areas and is a problem locally in New York. Iron content is also high throughout the area.	The Camillus Shale unit contains gypsum which is highly soluble. Solution has removed gypsum beds, particularly near streams and created a high porous rock. The Camillus Shale is the most productive aquifer in the region. The Buffalo and northeastern area is most critical as both bedrock and surficial deposit waters are too mineralized for public use.
Paleozoic	Devonian	Conneaut Canadaway Java-Genesee Hamilton	Shale and siltstone	0-2600	0		
	Silurian	Onondaga Akron	Carbonates	0-175	3.2-12.6		
		Camillus	Shale	0-400	0-63		
		Lockport	Dolomite	150	9.5		

Source: Modified from Great Lakes Basin Commission (1975a) and Geraghty and Miller (1977); includes data from LaSala (1968) and Great Lakes Basin Commission (1975b).

Silurian System

3.012
The Akron carbonates, Camillus Shale, and Lockport dolomites provide moderate to high-yielding aquifers. In the Lake Erie region, Silurian aquifers become too saline for use when overlain by saline beds. Freshwater zones in this aquifer occur in the Sandusky River Basin, Ohio, and in the Tonawanda Creek Basin, New York. Beneath the Silurian aquifer, saline water is present throughout the Lake Erie region (Great Lakes Basin Comm. 1975a).

Devonian System

3.013
The Canadaway Formation and the Conneaut and Conewango groups are predominantly shales and sandstones that yield very small amounts of water. Most of the shale sections are not water-bearing, but sandstone beds generally are capable of yielding small quantities of water (less than 1 L/s) (Geraghty and Miller 1977). The Ohio Shale (also known as the Chagrin Shale), which underlies much of the lower-lying land including the lake plain, is a very poor but important aquifer. These shales are overlain by glacial till in much of the region. The Ohio Shale is important because it is the only source of water over a large region. Potable groundwater is found near the till/shale contact in the uppermost (possibly weathered zone) of the shale. At greater depths, the Ohio Shale contains saline water, high in total dissolved salts.

Mississippian System

3.014
Rocks comprising the Pocono Group consist of alternating sandstones and shales. Shale units are generally not water-bearing, but sandstones (Cussewago, Berea, and Sharpsville) are important aquifers in the central and eastern parts of the Lake Erie region, capable of yielding small to moderate supplies of water.

Cussewago Sandstone

3.015
The Cussewago is the most permeable of the three Mississippian sandstones, which is reflected in somewhat better yields and higher specific capacities. In Ashtabula and Trumbull counties (Ohio), the average yield of wells drilled into the Cussewago Sandstone has been about 1.7 L/s. In western Crawford County (Pa.), the yield has ranged between <0.1 and 8 L/s, averaging about 1.3 L/s. Water from the Cussewago is generally of good quality, but hard and high in iron.

Berea Sandstone

3.016
The Berea Sandstone is also an important aquifer in the region and is tapped by water wells in southern Ashtabula County (Ohio) and Crawford County (Pa.). The average yield of Berea Sandstone wells in Ashtabula County has been about 1.4 L/s; in Crawford County, the yield has ranged from 0.3 to 4 L/s, averaging about 1 L/s. In some areas, the Berea Sandstone directly overlies the Cussewago Sandstone, and the two formations form a single aquifer with relatively high yield. The quality of water from the Berea Sandstone is generally good, but

hard to very hard, with dissolved solids concentrations between 200 and 300 mg/L, and occasionally high in iron.

Sharpsville Sandstone

3.017
The water-bearing characteristics of Sharpsville Sandstone are quite similar to those of the Berea and Cussewago sandstones. The yield from wells completed in the Sharpsville Sandstone in western Crawford County has ranged from <0.1 to 8 L/s, averaging about 1 L/s. The quality of water from the Sharpsville Sandstone is assumed to be similar to that of the other Mississipian sandstone aquifers (Geraghty and Miller 1977).

Pennsylvanian System

3.018
The Pottsville Formation is of little importance as an aquifer due to its limited extent and topographic position. Where the formation is saturated, it should be capable of yielding small to moderate supplies of water to wells.

Pleistocene and Recent Deposits

3.019
Various types of unconsolidated deposits are present in the landward portions of the Lake Erie region. The bulk of these deposits consists of glacial till and fine-grained deposits that are of little or no use as groundwater supplies. In contrast, stratified and sorted sands and gravels deposited as outwash, valley-train, or kame deposits in the eastern portion of the region are excellent aquifers. Together, these formations provide a large reserve of water which remains largely untapped.

Outwash and Ice-Contact Deposits

3.020
Sand and gravel deposits of glacial origin are present in many of the current river valleys and in the buried valleys of the Lake Erie region. Buried valleys are fairly common and such valleys have been mapped in Erie and Crawford counties, Pennsylvania, and in northeastern Ohio. Sands and gravels within the buried valleys and in glacial ice-contact deposits are capable of high yields if saturated and if an adequate source of recharge exists. Where these aquifers are in hydraulic connection with a river or stream, induced infiltration of surface water would result in high yields from wells.

3.021
Yield has ranged from 0.1 to 130 L/s in wells tapping sand and gravel deposits in western Crawford County. In Erie County (Pa.), yields of wells tapping glacial outwash are lower. The yield of sand and gravel wells has ranged from <0.1 L/s to 5 L/s. The outwash and ice-contact deposits constitute the most important aquifers in the landward portion of the Lake Erie region. The quality of water from the sand and gravel aquifers is generally good, but frequently hard and containing excessive concentrations of iron.

Lake Deposits

3.022
The Lake deposits are generally fine-grained and of low permeability and are not usually considered aquifers. The exception is where more coarse material was deposited--e.g., as ancient dune, beach, or spit deposits; if saturated, these sands can constitute aquifers of local importance. However, over most of the lake plain area, ancient beach deposits are thin or only partially saturated, and are not considered useful aquifers.

3.023
In northeastern Pennsylvania, a number of municipal water systems along Lake Erie are supplied by wells drilled in beach-sand deposits. Yields of these public supply wells are reported to range from 3 to as much as 30 L/s. In Ashtabula County (Ohio), several large-capacity wells have been developed in a beach-gravel aquifer west of Conneaut (Ohio). These beach aquifers are exposed and quite vulnerable to contamination.

Till Deposits

3.024
Due to the relatively impermeable nature of the till, till deposits are not considered aquifers. Occasionally, lenses of sand or gravel are interbedded within the clays and silts, and such permeable zones might yield small volumes of water to wells.

3.025
In Erie County (Pa.), the yields of domestic wells developed in moraine deposits have ranged from <0.1 to 5 L/s, with a median of 0.7 L/s. The sand or gravel lenses in the till deposits are only of importance in the lake plain area where the only alternative source of groundwater is the Devonian Shale. Because the shale often contains saline water and is high in total dissolved solids, many domestic wells obtain water from the overlying moraine deposits.

3.026
As summarized in Table 3-1 and detailed above, water-bearing formations of early Devonian age (e.g., below the Ohio Shale) and older contain saline and/or highly mineralized water of poor quality in most areas. Water from the Devonian-Silurian carbonate aquifer is very hard, highly mineralized, and of fair to poor quality. As the stratigraphic relationships in the Lake Erie region exhibit a generally southeasterly dip, the depth to saline waters increases southward from the Lake. Conversely, in the northerly lakeward direction, these saline zones decrease in depth and are less shallow. In addition to dipping to the southeast, the overlapping of younger strata also acts to increase the depth to saline zones as well as provide additional aquifers containing higher quality water in permeable zones or units. As a result, groundwater use in the Lake Erie region typically increases with distance inland from the Lake. This is also due in part to the availability of fresh lake water to water users near the Lake. There are no known water wells developed for groundwater supply in the Lake.

WATER QUALITY

3.027
Lake Erie, the shallowest lake in the Great Lakes System, has an area of 9910 mi^2, a volume of 116 mi^3, and an average outflow rate of 5920 m^3/s (Upchurch 1976). The mean detention time of water in the Lake is 2.5 years; the mean detention time is an important determinant of overall lake water quality, whereas other factors such as the amount, rate and method of release of contaminants, as well as current patterns and removal mechanisms, determine local concentration patterns. A review of contemporary literature by McGregor et al. (1978) concerning contaminant loadings, contaminant concentrations, and physical and chemical limnology in Lake Erie is presented in Appendix E.

3.028
Increasingly high inputs of nutrients (phosphorus and nitrogen) to Lake Erie since the 1800s has resulted in its highly eutrophic state and associated extensive anoxic hypolimnetic conditions reported during the early 1970s. It is this aspect of Lake Erie's water quality that has received the most widespread attention (Sly 1976). Recognition of deteriorating or adverse conditions of the Lake prompted signing of Canada/U.S. water quality agreements in 1972 and 1978, and initiation of massive remedial action.

3.029
A reconnaissance survey of hydrocarbon concentrations in Lake Erie has been completed (Zapotosky and White 1980). Average concentrations of lightweight hydrocarbons indicative of petroliferous natural gas--i.e., ethane, propane, and isobutane--were slightly higher in Canadian waters (4.9, 2.8 and 0.6 µg/L, respectively) than in American waters (1.9, 2.0, and 0.5 µg/L, respectively). Sources of these hydrocarbons, natural or anthropogenic, could not be determined.

3.030
Natural shoreline erosion and turbulent resuspension are the dominant sources of suspended sediments in Lake Erie (Sly 1976). Anthropogenic sources, however, have resulted in increased sediment input from tributary sources. The flow and water quality, including suspended solids loadings, of tributary streams varies with seasonal rainfall. There is no clear evidence of an increased concentration of suspended solids in Lake Erie related to these anthropogenic sources (Sly 1976).

3.031
Data on water current patterns in Lake Erie have been summarized by Hamblin (1971). Currents far from shore are highly variable in speed and direction, depending strongly on wind patterns. Current speeds are generally greatest near the lake surface, and decline with depth in the water column to low values near the bottom. Speeds greater than 54 cm/s have been observed in the open lake, but such high values are rare (Hamblin 1971).

3.032
Close to shore, the net current is parallel to the shoreline, with the direction of movement depending upon recent wind direction. If the wind is strong, current speed may vary markedly with depth--maximum speed being near the water surface and lowest speed near the bottom (Liu et al. 1976). During periods of onshore or offshore winds, surface currents tend to be in the direction of the

wind stress. Currents near middepth are essentially parallel to the shoreline and return flow occurs near the bottom to maintain continuity (Saylor 1966); net flow remains parallel to shore.

3.033
The width of the zone of shore-parallel currents in the Great Lakes is variable, depending upon numerous factors, including wind conditions (Liu et al. 1976) and upwelling (Mortimer 1975). Mortimer (1975) cited a study indicating that current patterns characteristic of the nearshore zone extend 2 to 10 miles from the shoreline of Lake Michigan, and Boyce (1974) presented data indicating that the transition between shore-parallel current patterns and those of the main body of Lake Ontario occur at 5-10 miles from shore in the summer, with similar, though less well-defined trends, in spring and fall.

3.034
Although the direction of nearshore currents near the shoreline may reverse in response to wind stress, the predominant direction of flow along the U.S. shoreline of the central and eastern basins of Lake Erie is northeastward. This might be expected from the approximately southwest-northeastward orientation of the long lake axis, "essentially parallel to the prevailing southwest winds" (Hamblin 1971).

AQUATIC ECOLOGY

Lake Erie

3.035
The current assemblages of phytoplankton, zooplankton, benthic macroinvertebrates, and fishes in the Lake Erie ecosystem represent an integrated response to weather, climate, contaminant concentrations, nutrient enrichment, alteration of the watershed, commercial exploitation of fish, and other factors.

Plankton

3.036
Plankton consists of small free-floating or motile plants (phytoplankton) and animals (zooplankton). Complex interrelationships exist among the various components of these groups. Chlorophyll-bearing plants, such as algae, usually constitute the greatest portion of the plankton biomass. Phytoplankton use the energy of sunlight to metabolize inorganic nutrients and convert them to complex organic materials. Zooplankton and other herbivores graze upon the phytoplankton and, in turn, are preyed upon by other organisms, thus passing the stored energy along to larger, and usually more complex, organisms. In this manner, nutrients become available to large organisms such as macroinvertebrates and fish.

3.037
Phytoplankton biomass in the central and eastern Lake Erie basins is dominated by diatoms and phytoflagellates, respectively. Currently, the genera Fragilaria (diatom) and Cryptomonas (flagellate) are most abundant in the Lake. Both genera are tolerant of eutrophic conditions (Munawar and Munawar 1975, 1976).

3.038
The zooplankton community in Lake Erie is characterized by pulses of one, two, or more generations of short-lived crustaceans with high reproductive potentials. Although the dominance of zooplankton species changes over time, generally cyclopoid copepods dominate much of the year far from shore and cladocerans and calanoid copepods are abundant near the shore. Important genera are Diacyclops (cyclopoid copepod), Bosmina, Eubosmina and Daphnia (cladocerans) and Diaptomus (calanoid copepod) (Watson 1976).

Macrophyton

3.039
Aquatic macrophytes (aquatic plants possessing a multicellular structure with cells differentiated into specialized tissues) are natural components of most aquatic ecosystems and are found in Lake Erie. The primary production of macrophytes in Lake Erie is less than that of phytoplankton. Macrophytes provide habitat for many aquatic organisms and add stability to shoreline areas. Lake Erie macrophyte communities usually are found in shallow water where sunlight can reach the bottom and in areas not receiving the full force of the wind and waves.

Benthic Macroinvertebrates

3.040
Benthic macroinvertebrates can be defined by location and size but not by position in the trophic structure since they occupy virtually all levels. They may be omnivores, carnivores, or herbivores; in a well-balanced system, all three types likely will be present. They include deposit and detritus feeders, parasites, scavengers, grazers, and predators. Marked variation in macroinvertebrate species composition occurs among various parts of the Lake. Distribution of many species seems to be associated with the progressively more eutrophic conditions encountered toward the western basin. Three important benthic groups represented in Lake Erie are oligochaetes (aquatic worms) which are most abundant in the central and eastern basins; pelecypods (clams) which are abundant in the shallow shore zones and sand ridges near islands and between the central and eastern basins; and chironomids (midges) which have the greatest species diversity in the eastern basin. Chironomid populations in the eastern basin include several species indicative of oligotrophic conditions (Brinkhurst et al. 1968).

3.041
Benthic macroinvertebrate communities have undergone significant changes in both species composition and abundance. One factor which accelerated this change was expansion of an anoxic zone in the hypolimnion of the central and western basins. Increased contaminant loading also has contributed to drastic changes, most notably in the western basin (Britt et al. 1977).

Fishes

3.042
Fish occupy the upper trophic levels of the aquatic food web and are directly and indirectly affected by chemical and physical changes in the environment. Water quality conditions that significantly affect the lower levels of the food web will affect the abundance, species composition, and condition of the fish population.

3.043
Lake Erie ichthyofauna is comprised of 114 species from 24 families (VanMeter and Trautman 1970). Members of the families Cyprinidae (minnows), Percidae (perches), Catostomidae (suckers), Centrarchidae (sunfishes), and Ictaluridae (catfishes) account for 74% of the species. Spawning areas of fishes (Table 3-2) are primarily inshore in shallow water (perches, sunfish, minnows, and catfish) or in tributary streams (perches, suckers, minnows) (Carlander 1969, 1977; Scott and Crossman 1973). Nursery areas are inshore in shallow water; feeding areas vary according to food organism availability and habitats of different fish species. Present spawning grounds are not well defined, and states bordering Lake Erie consider most nearshore waters as potential spawning sites (Hartley and Van Vooren 1977; N.Y. Dep. Environ. Conserv. 1977; Great Lakes Basin Comm. 1975c).

Lake Erie Region Streams

3.044
The tributary streams of the Lake Erie region present a variety of environmental conditions, resulting in a diversity of communities of plankton, macrophytes, macroinvertebrates, and fishes.

Plankton

3.045
Flowing water in the study region contains representatives of phytoplankton, zooplankton, and drifting macroinvertebrates, although the latter may not be considered part of the plankton community. Phytoplankton are usually more abundant than zooplankton, and diatoms are almost always dominant. During the summer months, truly planktonic diatoms (such as *Asterionella*, *Fragilaria*, and *Melosira*), planktonic rotifers (such as *Keratella*, *Notholca*, and *Brachionus*), and several cladoceran and copepod species may be present. In headwaters, "true" plankters are presumably strays from other bodies of water, i.e. marshes and impoundments, draining into the streams. In slower stretches of the tributaries, the variety and quantity of plankton and the truly planktonic species increase. In the larger rivers such as the Cuyahoga River (Ohio), some plankton is always present and true plankters often predominate.

Macrophyton

3.046
Aquatic macrophytes are present in Lake Erie tributaries. The type and abundance of this group of primary producers depends upon the variation in habitat, including water quality, along the various watercourses. In upper reaches, where stream velocities are high, representatives of the river weed (*Podostemum*) and moss (*Fontinalis*) families may be found. In the slower reaches, typical macrophytes may be pondweed (*Potamogeton*), water lily (*Nuphar*), water milfoil (*Myriophyllum*), and frogbit (*Vallisneria*). A wide variety of rooted aquatic plants may also be present in the watershed where tributaries are fed by impoundments, marshes, and other "pond-like" bodies of water.

Table 3-2. Spawning Habits of Lake Erie Fishes

Family/Scientific Name	Common Name	Spawning Habitat Criteria[a] Depth	Substrate	Tributary Migration
CLUPEIDAE				
Alosa pseudoharengus	Alewife	Inshore	Sand and gravel	
Dorosoma cepedianum	Gizzard shad	Inshore	Sand and gravel	
SALMONIDAE				
Salvelinus namaycush	Lake trout	Inshore to offshore, usually < 40 ft	Rubble	
Coregonus artedii	Cisco, Lake herring	Inshore 3-10 ft	Variable	
OSMERIDAE				
Osmerus mordax	Rainbow smelt	Inshore	Gravel shoals	Yes
HIODONTIDAE				
Hiodon tergisus	Moon eye	Unknown		
CYPRINIDAE				
Cyprinus carpio	Carp	Shallows	Weedy areas	
Notropis atherinoides	Emerald shiner	Uncertain		
Notropis hudsonius	Spottail shiner	Shallows	Sandy shoals	Yes
Notropis spilopterus	Spotfin shiner	Shallows	Undersides of rocks, objects	
Notropis stramineus	Sand shiner	Uncertain		
Pimephales notatus	Bluntnose minnow	Shallows	Under rocks, objects	
CATOSTOMIDAE				
Catostomus catostomus	Longnose sucker	Shallows	Gravel and rock	Yes
Catostomus commersoni	White sucker	Inshore	Gravel and rock	Yes
Carpiodes cyprinus	Quillback	Flooded areas	Sand and mud	Yes
Moxostoma macrolepidotum	Shorthead redhorse			Yes
ICTALURIDAE				
Ictalurus punctatus	Channel catfish	Inshore	Holes, undercuts, rocks	Uncertain
Noturus flavus	Stonecat	Shallows	Rock	
GADIDAE				
Lota lota	Burbot	Shallows, 1-10 ft	Sand, gravel, shoals	
PERCICHTHYIDAE				
Morone americana	White perch	Shallows	Variable	
Morone chrysops	White bass	Inshore	Shoals	
CENTRARCHIDAE				
Ambloplites rupestris	Rock bass	Shallows	Variable	
Micropterus dolomieui	Smallmouth bass	Shallows	Sand, rock, gravel	
PERCIDAE				
Perca flavescens	Yellow perch	Shallows	Sand and gravel, vegetation	
Stizostedion vitreum	Walleye	Variable	Gravel shoals	Yes
SCIAENIDAE				
Aplodinotus grunniens	Freshwater drum	Shallows	Variable	
COTTIDAE				
Cottus bairdi	Mottled sculpin	Shallows	Rock, ledges	

[a]Blanks indicate either not applicable or unknown.

Macroinvertebrates

3.047
The tributaries of the Lake Erie region are typically slow-moving through agricultural regions. Although a wide variety of substrates is possible, most of the streams have soft, organic bottom material, and the macroinvertebrate groups most representative are Diptera (midges), Oligochaeta (aquatic earthworms), and Mollusca (mussels). In upper reaches of some of the tributaries in New York and Pennsylvania, water velocities are greater and the substratum is composed of rubble, gravel, and sand. The representative macroinvertebrate groups are Ephemeroptera (mayflies), Plecoptera (stonefies), Diptera, and Trichoptera (caddisflies).

Fishes

3.048
The small tributary streams that enter Lake Erie contain diverse fish communities. The species of fishes found in these streams depend primarily on the physical and chemical conditions of the stream. Slow-flowing turbid and channelized warmwater streams may have a diverse fish assemblage containing minnows, darters, sunfishes, catfish, carp, and bass, as well as other species (Trautman 1957). Colder water streams with steeper gradients contain some of the same species--e.g., minnows, darters, and sunfishes--but also have smallmouth bass, walleye, and perch, and, depending on stocking, may contain trout or migratory salmonids. Several reservoirs in the Onland Alternative Study Region are managed for a trophy muskellunge fishery.

3.049
There is a variable amount of exchange of fish between the lower reaches of these streams and the Lake. At any given time, fish from the Lake may enter and utilize the tributaries. Such exchange is predominant during the spring when migratory species enter the streams seeking spawning areas.

LAKE ERIE WATER USE

Recreation

3.050
Lake Erie and its shoreline, major stream valleys (Sandusky, Vermilion, Black, Cuyahoga, Chagrin, Grand and Cattaragus), and inland lakes [Mosquito Lake (Ohio), Berlen Reservoir (Ohio), Pymatuning Lake (Ohio-Pennsylvania) and Shenango Lake (Pennsylvania)] are major sites for water-use recreation in the Lake Erie region.

3.051
Swimming is the major beach activity, although supporting activities and complementary facilities are often located nearby--e.g., parking lots, restaurants, miniature golf courses, and shops. Fishing in Lake Erie is usually from a pier or boat. Tributary streams are also fished. Pleasure boating, sport fishing, and water skiing activities originate at marina facilities in most cases; shoreline harbors and boat-launch areas are concentrated near the urban centers. The region contains many scenic vistas, including lakes and stream valleys. Publicly owned parks provide beach, fishing, and boating facilities, as well as opportunities for passive enjoyment of water recreation.

3.052
Recreation property is owned both publically and privately; the size of land holdings ranges from beachfront cottages to Presque Isle State Park. Water-use recreation is a major factor in development and use of the Lake Erie shoreline.

Sport Fishery

3.053
The 1977 sport fishery catch in Ohio waters of Lake Erie was 1.1 million kg (Baker et al. 1978). Major species caught by sport fishermen were perch, white bass, freshwater drum, and channel catfish (21%, 25%, 26%, and 18%, respectively). A minor portion of the sport fishing effort and catch (1%) occurs during the winter ice fishing season. The majority of angler effort is expended in the western basin and Sandusky Bay (63%). Shore fishermen are less common than boat fishermen (40% vs. 60%), except in the area between Huron and Conneaut where shore fishermen account for approximately 66% of the effort. This area of Lake Erie receives approximately 37% of Ohio's sport fishery effort and produces approximately 20% of the catch. Areas of major fishing pressure between Huron and Conneaut are located near the population centers of Huron, Lorain, Cleveland, Fairport, Ashtabula, and Conneaut. In 1960, 476,079 anglers fished 8.5 million days on the U.S. waters of Lake Erie. By 2020, an estimated 708,500 anglers will fish 18 million days per year. The net economic value of the Ohio sport fishery averaged approximately $20 million annually between 1965 and 1979 (Baker et al. 1978).

3.054
In Pennsylvania, the Presque Isle area supports a large sport fishery. Although pawfish (bass, sunfish, and catfish) are most often caught, walleye are taken occasionally. During spring and fall, introduced coho and chinook salmon are also caught. The marshy lagoons support an abundance of species and are excellent spawning habitat for some species, primarily bass, sunfish, and pike. In New York, the sport fishery in the Lake proper consists of all the major sport species. However, a significant sport fishery exists on the tributaries to the Lake, e.g., Chautauqua, Cattaraugus, Delaware, Big Sister, and Eighteen Mile creeks (N.Y. Dep. Environ. Conserv. 1977). The spawning runs of trout and salmon in these streams are heavily fished. The nearshore zone of both Pennsylvania and New York contain spawning areas for most species.

Commercial Fishery

3.055
The commercial fishery in Lake Erie is dominated by smelt and yellow perch. Less desirable rough fish, e.g., carp and freshwater drum, are also important to the fishery (Regier 1973).

3.056
The dominant types of capture gear utilized are gillnets and trawls. Commercial fishing may occur in all U.S. waters except where presently prohibited (e.g., some regions of the western basin). Ohio considers all state waters potential fishing grounds. There have been conflicts between Canadian gas developments and commercial fishermen. The most common event is net entanglement on wellheads. Many Canadian wells, however, are covered with trawl deflectors to prevent entanglement.

3.057
In 1977, the total commercial harvest from Lake Erie was approximately 19.5 million kg. The Canadian fishery took 80% and the U.S. fishery 20%, or approximately 3.9 million kg (Ohio Dep. Nat. Resour. 1977). Ohio's commercial fishery is by far the major component of the U.S. fishery, accounting for 90% of the total U.S. harvest from Lake Erie. Ohio's commercial harvest in 1977 was valued at $2.4 million. Revenue to the state of Ohio was $50,450 from commercial licenses and about $10,500 in royalty fees for a total of $61,000 (Ohio Dep. Nat. Resour. 1977). Commercial fishing is minor in New York and is centered primarily in the Dunkirk area. In Pennsylvania, it is doubtful that commercial fishing still takes place.

Municipal and Industrial Water Supplies

3.058
Thirty-four municipal and industrial potable-water intakes in the Lake Erie Study Region are listed in Table 3-3. These intakes vary from a distance of 246 ft to 3.4 miles offshore, and are located 5 to 40 ft below the surface.

3.059
Seven of the water purification facilities in the Lake Erie Study Region have plant capacities of 10 million gallons per day (MGD) or greater. As shown in Table 3-4, all seven plants employ conventional water treatment processes for surface water. Treatment includes chlorination, coagulation, clarification and filtration. Five locations use activated carbon for control of tastes and odors. Other treatments include fluoridation--to prevent caries (tooth decay)--and pH adjustment through addition of lime or caustic soda. Many of the water treatments listed for these plants may be used by other water supply facilities listed in Table 3-3, although the range of treatment options is likely to be limited for many of the smaller plants.

3.060
With treatment technologies fully developed and readily available, it is possible to remove or reduce the concentrations of many of the contaminants associated with offshore natural gas drilling activities. Current procedures used by the seven water purification facilities listed in Table 3-4 are presented in Table 3-5.

3.061
Adsorption on activated carbon is generally used for removal of organics. Reduction of phenol concentrations is accomplished by an oxidation process using potassium permanganate, or by adsorption onto activated carbon.

3.062
Hydrogen sulfide, which produces an objectionable odor, can be oxidized rapidly to sulfate with the use of chlorine or potassium permanganate. Other sulfur components can be controlled by adsorption onto activated carbon or through precipitation with alum.

3.063
High levels of turbidity (clays) encountered at the purification facilities are treated by adjusting the dosage of coagulant.

Table 3-3. Potable Water Intakes in Lake Erie Study Region[a]

Intake (from East to West)	Intake Depth[b] (m)	Distance from Shore (m)
<u>New York</u>		
Shore Haven	2.7	75
Forest Park	2.7	75
Westfield	2.7	75
Dunkirk	6.7	470
Evans	2.7	510
Sturgeon Point	7.3	760
Pinehurst	1.5	150
Wanakah	1.5	240
Woodlawn[c]	5.2	1100
	5.2	910
Buffalo	5.2	2010
<u>Pennsylvania</u>		
Erie[c]		
Sommerheim	6.7	2500
Chestnut St.	6.7	370
<u>Ohio</u>		
Sandusky	4.9	880
Plum Broom Ordnance Works	4.9	910
Huron[c]	3.4	640
	1.5	240
Vermilion	2.4	370
Elyria	3.6	370
Lorain	3.6	340
Avon Lake	6.1	610
Cleveland[c]		
Crown	5.8	4000
Division Ave.	8.8	6100
Baldwin	8.8	5200
Nottingham	12.2	5500
Mentor Township Park	4.3	610
Painesville	4.3	1000
Fairport Harbor	2.4	380
Diamond Alkali Company	4.6	890
Industrial Rayon Company	5.5	1200
Madison	4.9	550
Ashtabula	5.5	510
Union Carbide Metals Company	6.4	1000
Conneaut	4.3	610

[a] Data obtained from personal communication (1979) with Faustel, Lincoln, Taylor, and Woods, and from U.S. Department of Commerce (1974-1977) maps.

[b] Depth below low-water datum (173.31 m above sea level).

[c] Multiple intakes.

Table 3-4. Procedures Used for Treatment of Lake Erie Water by Water Purification Facilities Having Capacities ≥ 10 MGD[a]

	Buffalo, N.Y.	Erie, Pa.	Sandusky, Ohio	Vermilion, Ohio	Elyria, Ohio	Avon Lake, Ohio	Cleveland, Ohio
Plant capacity (MGD)	180	87[b]	11	10	35	42	575[c]
Emergency intake/discharge	Alternative supply	-	Bypass system	Alternative supply	-	-	-
Procedure							
Disinfection/oxidation	Chlorine	Chlorine	Chlorine	Chlorine	Chlorine/potassium permanganate	Chlorine	Chlorine/potassium permanganate
Coagulation	Alum	Alum	Alum	Alum/lime	Alum/coagulant aid	Alum	Alum/lime
Adsorption	Powdered activated carbon	Granular activated carbon	-	-	Powdered activated carbon	Powdered activated carbon	Powdered activated carbon
Filtration	Sand/anthracite	Sand	Sand/anthracite	Sand	Sand/anthracite	Sand	Sand
pH adjustment	-	Lime/caustic soda	Caustic soda	Lime	Lime	Lime	Lime
Auxiliary treatments	-	-	-	Fluoridation	Flouridation	Fluoridation	Fluoridation

[a]MGD = million gallons/day. Data obtained by personal communication as follows: Walshuck (Sandusky, Ohio), 1978; Beston (Vermilion, Ohio), 1979; Moore (Elyria, Ohio), 1979; Plavlachan (Avon Lake, Ohio), 1979; Jefferies (Cleveland, Ohio), 1978; Jacquel (Erie, Pennsylvania), 1978; O'Connor (Buffalo, New York), 1978.

[b]Total capacity of two plants.

[c]Total capacity of four plants.

Table 3-5. Procedures Onsite or Readily Available to Selected Water Purification Facilities on Lake Erie for Treatment of Contaminants Associated with Offshore Natural Gas Drilling Activities[a]

Contaminant	Buffalo, N.Y.	Erie, Pa.	Sandusky, Ohio	Vermilion, Ohio	Elyria, Ohio	Avon Lake, Ohio	Cleveland, Ohio
Organics	-	Adsorption	-	-	Adsorption	-	-
Phenol	-	Adsorption or oxidation	-	-	Adsorption or oxidation	-	-
Sulfur compounds	Coagulation	Adsorption	Oxidation	-	Oxidation or coagulation	-	Oxidation
Heavy metals	Coagulation	-	Coagulation	-	Adsorption or coagulation	Coagulation	Coagulation
Clays (turbidity)	Coagulation	Coagulation	Coagulation	Coagulation	Coagulation	Coagulation	Coagulation
HCl (low pH)	-	Lime or caustic soda	-	Lime	Lime	Lime	-
Total dissolved solids	Increased coagulant dosage	Increased coagulant dosage	-	Increased coagulant dosage	-	-	-

[a]Data obtained by personal communication (see footnote to Table 3-4).

3.064
Heavy metals may be precipitated by adjusting the pH; suspended material may then be removed from solution by coagulation using alum or lime. Activated carbon may also be helpful in reducing dissolved metal concentrations; its use has resulted in fairly high removal efficiences at neutral or high pH (Sigworth and Smith 1972; Dean et al. 1972; Culp et al. 1974, 1978).

3.065
Because Lake Erie is highly buffered, the purification facilities contacted did not consider treatment for low pH conditions necessary. But if an acid spill were to occur at the intake, pH adjustment could be made by adding lime or caustic soda.

3.066
The only procedure available for removal of high concentrations of total dissolved solids (TDS) is coagulation, using an increased dosage of alum. This process has a low removal efficiency for TDS. The preferable limit for TDS in drinking water is 500 mg/L (USEPA 1976). As a result, concentrations of TDS below 500 mg/L are not considered a threat to the facilities [personal communications (1978) with Walshuck, Jefferies, Jacquel, and O'Connor; (1979) with Heston, Moore, and Plaviachan].

3.067
To date, no hydrocarbon spills have been reported for Lake Erie which have had adverse affects on the water supplies of any of these seven large purification facilities. However, analysis of the Cleveland water supply for organic contaminants showed the presence of from 21 to 36 compounds (Sanjivamurthy 1978). Hydrocarbon sources are discussed in the section on Water Quality.

3.068
Three of the plants have emergency intake/discharge systems. At the Sandusky, Ohio facility, contaminated water can be discharged into the bay before reaching the plant. At the plants in Vermilion, Ohio and Buffalo, New York, secondary intakes are located in alternative water supplies [personal communications (1978) with Walshuck; and (1979) with O'Connor and Heston].

Municipal/Industrial Wastewater Disposal

3.069
There are approximately 450 municipal and industrial outfalls in the Reference Program Study Region that discharge directly into Lake Erie. The flow rate of these discharges varies from 1×10^{-3} to 400 MGD (USEPA 1979; Wellington 1979--personal communication; N.Y. Dep. Environ. Conserv. 1980). The number of outfalls per type of liquid waste discharged is: industrial waste, 240; electric utility waste (thermal and chemical), 9; and sanitary waste, 202.

3.070
Industrial discharges into Lake Erie vary widely depending upon the type of process. However, all industrial dischargers into Lake Erie must meet their process-specific effluent limitations. A detailed description of industrial discharges into Lake Erie is presented in two industrial discharger survey documents (USEPA 1979; N.Y. Dep. Environ. Conserv. 1980).

3.071
The nine existing electric power generating stations have been granted NPDES or SPDES permits to discharge thermal and chemical wastes into Lake Erie. Effluent limitations restrict the one-day maximum concentration in discharges from steam generating facilities to 20 mg/L for oil and grease and 0.5 mg/L for free available chlorine (40 CFR 423).

3.072
Discharge of sanitary waste into the Reference Program Study Region occurs from high-volume municipal wastewater treatment plants as well as from small-volume dischargers such as private residences. The degree of treatment and amount of monitoring required is based on the volume of waste discharged.

3.073
The six major outfalls in the study area which discharge chlorinated effluent directly into Lake Erie are listed in Table 3-6. The outfalls are located 110 to 3200 m offshore. All six of the outfalls are from municipal wastewater treatment plants using conventional wastewater treatment processes. Five of the plants use primary sedimentation, secondary-biological treatment by the activated sludge process, and chlorination. The sixth plant, Westerly, uses only primary sedimentation and chlorination, but is being upgraded to a physical/chemical treatment plant (Sargent 1979--personal communication).

Table 3-6. Major Municipal Wastewater Treatment Plants Having Outfalls in the Reference Program Study Region[a]

Plant Location	Process	Plant Capacity (MGD)	Residual Chlorine (mg/L)[b]	Outfall Distance from Shore (m)
New York				
Dunkirk	Sedimentation, activated sludge	6	0.5-1.0	760
Pennsylvania				
Erie	Sedimentation, activated sludge	64	0 -1.0	3200
Ohio				
Avon Lake	Sedimentation, activated sludge	5	0.2-0.7	370
Cleveland Westerly	Sedimentation	80	0.1-0.5	110
Cleveland Easterly	Sedimentation activated sludge	400	0.1-0.5	110
Mentor	Sedimentation, activated sludge	8	0.7	700

[a]Data obtained by personal communication (1979) as follows: Killinger (Avon Lake, Ohio); Sargeant (Cleveland, Ohio); Fredebaugh (Mentor, Ohio); Haburski (Erie, Pennsylvania); Sandel (Dunkirk, New York).

[b]At chlorine contact chamber outlet.

At the outlet of the chlorine contact chambers for each plant, residual chlorine concentrations are restricted to 1.0 mg/L, and are reduced to undetectable levels prior to reaching Lake Erie.

Ports, Shipping, and Navigation

3.074
The Great Lakes System is the largest body of navigable fresh water in the world. Most of the system consists of a series of end-to-end links, one of which is Lake Erie. Interruption of traffic through any one of the links could disrupt traffic in the entire system. Great Lakes ports are undergoing major changes; many categories of lake shipping are disappearing, and there has been a sharp decline in general cargo trade, with a considerable trend toward "load centers" at a few major ports (Schenker et al. 1976).

3.075
Inbound ship traffic to Lake Erie harbors within the Reference Program Study Region increased during the early 1970s, but has declined since 1973 (Table 3-7). Ship traffic is composed primarily of passenger and dry cargo vessels (Table 3-8).

TERRESTRIAL ECOLOGY

Physical Features

3.076
A considerable range of climatic conditions exists in the Lake Erie region. Mean monthly temperatures range from about 20°F in January to about 80°F in August (Sly 1976; U.S. Geol. Surv. 1970). Extreme temperatures range from -20°F to 100°F. For most of the region, the freeze-free period is only five months, from June to October. The shoreline areas near Lake Erie have the additional freeze-free months of May and November due to the moderating influence of the large mass of water. Precipitation is fairly evenly spread throughout the year (about 2-3 in./mo). A slight precipitation gradient exists from west to east across the region, resulting in higher snowfall in the Pennsylvania/New York area. Mean annual precipitation (32 to 48 in.) is approximately equal to mean annual pan evaporation (32 to 40 in.). The climate is generally humid and the region is subject only to short droughts. Prevailing winds are from the southwest throughout the year.

3.077
From west to east, the land surface (formed by past glaciation) changes from a smooth, gently sloping plain to rolling plains, tablelands of moderate relief, and lake plain. In the eastern counties, the terrain is tablelands of considerable relief and open high hills and glaciated valleys (U.S. Geol. Surv. 1970; Great Lakes Basin Comm. 1975e) (see Figure 3-1). Imposed on this general trend are several prominent linear sand beaches (remnants of glacial lakes) parallel to the Lake Erie shore, as well as bedrock exposures and gorges in the eastern plateau. Within this varied terrain, elevation ranges from less than 700 ft at Lake Erie to more than 2400 ft in the Allegheny Plateau.

3.078
Soils are derived from parent materials that vary from hard crystalline rock to lake plain sands and clays. They range in texture from loams, to silt- or silty-clay loams, to sandy loams (Int. Joint Comm. 1976). The soils belong to

Table 3-7. Inbound Ship Traffic for Lake Erie Harbors Within the Reference Program Study Region, 1968-1977[a]

Harbor	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
New York										
Buffalo	1,434	1,383	1,337	1,087	826	1,166	992	826	929	733
Pennsylvania										
Erie	1,112	1,453	1,843	1,865	1,437	1,963	1,738	2,011	1,345	1,105
Ohio										
Ashtabula	579	825	1,007	930	813	805	1,096	781	775	864
Cleveland	2,564	2,857	2,562	2,819	2,801	2,838	2,798	2,452	1,791	2,131
Conneaut	784	1,232	1,206	1,273	1,316	1,233	959	1,325	1,171	1,370
Fairport	194	253	400	365	402	436	448	350	528	618
Huron	134	669	542	722	1,107	1,444	1,093	1,175	981	750
Lorain	1,759	1,952	2,119	1,694	2,043	2,175	1,989	1,467	1,407	1,108
Sandusky	4,114	6,144	6,050	5,287	6,729	5,874	5,320	5,368	5,394	5,247
Total	12,674	16,768	17,066	16,042	17,474	17,934	16,433	15,753	14,321	13,926

[a]Source: U.S. Army Corps of Engineers (1968-1977).

Table 3-8. Breakdown of Inbound Ship Traffic for Lake Erie Harbors Within the Reference Program Study Region, 1976 and 1977[a]

	Passenger and Dry Cargo		Tanker		Towboats and Tugboats		Dry Cargo Barges		Tanker Barges		Total	
Harbor	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
New York												
Buffalo	735	565	135	107	35	34	1	0	23	27	929	733
Pennsylvania												
Erie	1,316	1,079	19	3	6	11	0	2	2	10	1,345	1,105
Ohio												
Ashtabula	775	864	0	0	0	0	0	0	0	0	775	864
Cleveland	1,701	2,013	31	45	22	38	7	0	30	35	1,791	2,131
Conneaut	1,163	1,367	0	0	5	2	3	1	0	0	1,171	1,370
Fairport	528	618	0	0	0	0	0	0	0	0	528	618
Huron	981	750	0	0	0	0	0	0	0	0	981	750
Lorain	1,386	1,076	11	1	5	15	0	1	5	15	1,407	1,108
Sandusky	5,394	5,247	0	0	0	0	0	0	0	0	5,394	5,247
Total	13,981	13,579	196	156	73	100	11	4	60	87	14,321	13,926

[a]Source: U.S. Army Corps of Engineers (1968-1977).

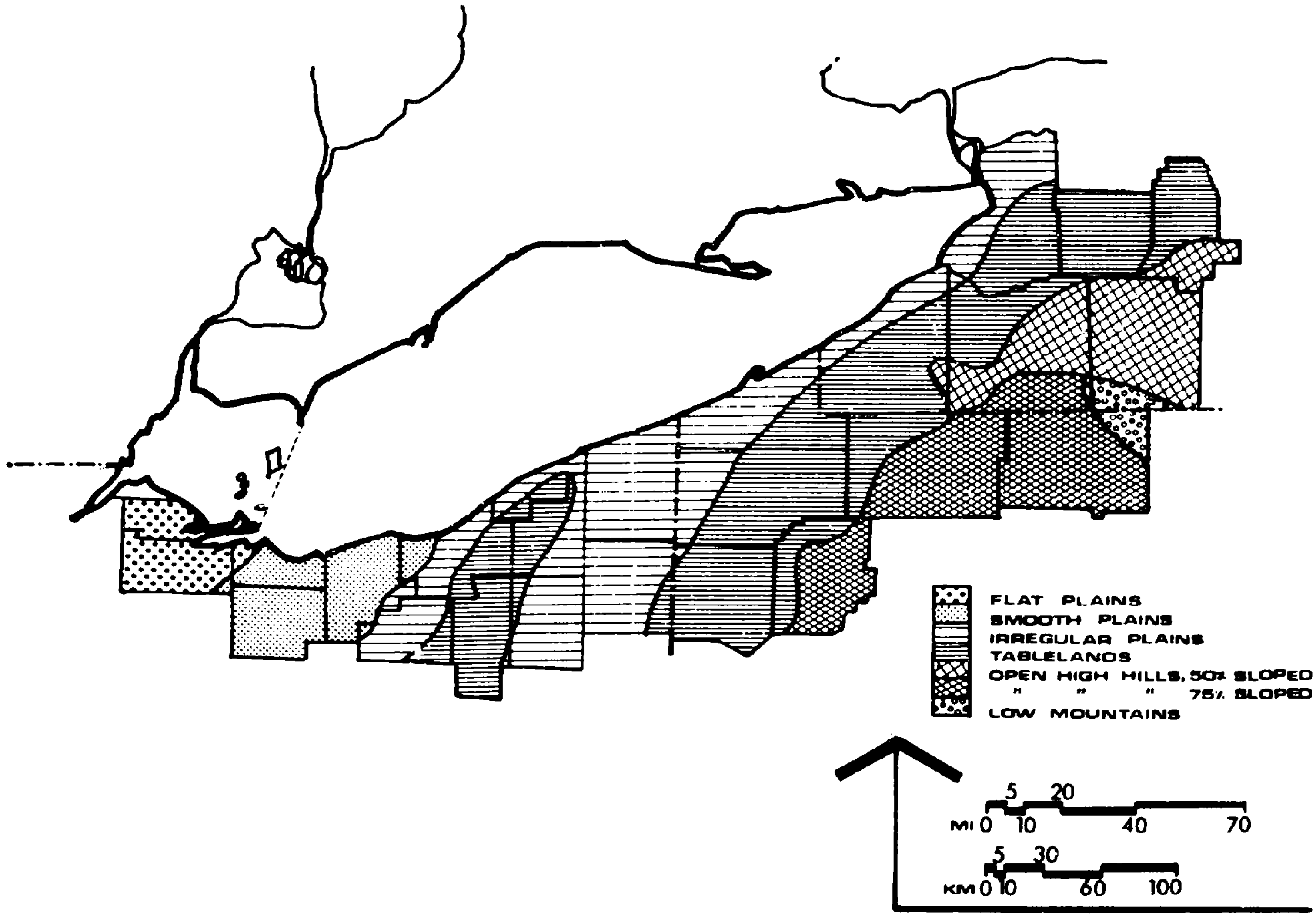

Figure 3-1. Surface Landforms in the Reference Program and Onland Alternative Program Study Regions.

two main groups (U.S. Geol. Surv. 1970): (1) udalfs in western counties and along Lake Erie and (2) fragiochrepts in the rest of the region. Udalfs are warm, moist soils with a gray-brown surface horizon and sometimes a fragipan, or subsurface horizon, of clay accumulation; these soils are used for row crops, small grain, and pastures; fragiochrepts are similar to the above but have weakly differentiated horizons. Where soils developed from sandstone and shale, poor drainage is a serious problem on agricultural land, particularly in northern Ohio and Erie County, Pennsylvania; erosion is a problem because of the fine texture and low permeability of the soil. In the Allegheny Plateau in the eastern part of the region, drainage is not a problem and the soils are not as inherently erodible; however, erosion can still be a problem because of the high runoff rate and long steep slopes.

3.079
Wetlands are scattered throughout the Lake Erie region (Great Lakes Basin Comm. 1975e; N.Y. Dep. Environ. Conserv. 1979). In Ohio, there are some inland wetlands of ecological significance--including bogs, fens, swamps, and marshes, as well as minor wetlands along creeks and springs; however, many of these wetlands are not in public ownership (Great Lakes Basin Comm. 1975e). In Pennsylvania, there is a concentration (compared to the rest of Pennsylvania) of several wetlands along streams in the inland part of Erie County and in Crawford and Mercer counties, and there are a few wetlands in Warren County. In addition, two notable inland wetlands are Conneaut Marsh and Pymatuning Swamp. Although Pennsylvania has no overall wetland policy at present, wetlands are considered to be a "critical resource area" (Pa. Gov. Off. State Plan. Dev. 1976). Few wetlands exist in New York, and the marsh in the Niagara River area near Buffalo is being displaced by harbor facilities (Great Lakes Basin Comm. 1975e).

Biological Features

3.080
Prior to the 1820s, most of the Lake Erie region was densely forested (Sly 1976). The distribution of the various natural forest types correlated with climatic/topographic/soils patterns (U.S. Geol. Surv. 1970). Along the Lake and in most of the western counties, where land was flat and climate more moderate, a beech-maple (Fagus-Acer) forest existed. In Erie County (Ohio) and parts of Lorain County (Ohio), elm-ash (Ulmus-Fraxinus) forest predominated. A northern hardwoods forest--with a mixture of deciduous and coniferous trees, maple-birch-beech-hemlock (Acer-Betula-Fagus-Tsuga)--characterized most of the eastern counties. In the hilly and cooler Venango County (Pa.) and parts of Warren (Pa.), Cattaraugus (N.Y.), and Allegany (N.Y.) counties, the Appalachian oak (Quercus) forest predominated.

3.081
Extensive clearing of forest ecosystems for agriculture, plus logging of most of the remaining forest, completely changed and severely simplified the vegetational communities on about half of the region and altered the remaining forest ecosystems. About one-third of the western half of the Lake Erie region is currently forested, mostly in small woodlots; whereas about one-half of the eastern part is forested, both in small woodlots and in larger tracts in state and national forests (Int. Joint Comm. 1976). Maple-beech-birch forests currently are scattered throughout most of region (U.S. Geol. Surv. 1970). Pockets of elm-ash-cottonwood (Ulmus-Fraxinus-Populus) can be found

along Lake Erie and in some valleys, with oak-hickory (Quercus-Carya) occurring on higher lands in the southeast and eastern counties and in Erie and Huron counties. In addition, small patches of white-red-jack pine (Pinus) can be found in the eastern counties, mostly in plantations.

3.082
Forests generally occur on land that is steep or has poor soils. About half the forest land is unmanaged or inadequately managed (Great Lakes Basin Comm. 1974). The greatest needs are protection from fire, insects, and disease; reforestation; grazing control; erosion control; improved harvesting; and protection from overuse and multiple use. Chemicals (pesticides, fertilizers, etc.) are not used extensively (Int. Joint Comm. 1974). As man has gradually harvested the accumulated growth of the past (Odum, E., 1971; Odum, H.T., 1971; Likens et al. 1977), trees are being harvested at earlier ages. The road system in the larger tracts of forestland in the eastern counties is not well developed. Thus, logging roads and skid trails often cover 10-15% of an area (Int. Joint Comm. 1974).

3.083
Agricultural ecosystems comprise about one-third of the western counties and one-half of the eastern counties of the Lake Erie region. About half the croplands require treatment to reduce runoff, erosion, and sedimentation, and to improve drainage (Great Lakes Basin Comm. 1974). Agricultural ecosystems are disappearing in the region due to abandonment of economically marginal lands (followed by reversion to old-fields and forest) and to urbanization, especially near large cities.

Wildlife

3.084
The ecosystems of the Lake Erie region support a diversity of wildlife (Great Lakes Basin Comm. 1975e). Restricted access to private land is the most important problem with regard to wildlife use (consumptive and nonconsumptive). In northeastern Ohio, agricultural ecosystems are reverting to early successional stages of natural ecosystems, which results in improved upland game habitat but decreased habitat for seedeaters such as pheasant and bobwhite quail. The younger stands of forest support medium densities of white-tailed deer and ruffed grouse, as well as populations of cottontail rabbit, squirrel, muskrat, pheasant, and raccoon, which are harvested by man. Raptors continue to decline because of reproductive failure due to pesticides. The most serious adverse impact to wildlife in northeast Ohio is the diminishing resource base because of expansion of the Cleveland-Akron metropolitan area.

3.085
The Pennsylvania area along Lake Erie is similar to northeast Ohio, but it is more hilly and wooded, and even more land is reverting to forest ecosystems. Only the open water of Lake Erie and Erie Bay are used by waterfowl, both during migration and over winter. A thermal outfall from an electric power plant keeps the water open east of the bay. The value of these areas has declined due to pollution-caused reduction of food organisms (Great Lakes Basin Comm. 1975e). Inland streams support high populations of muskrat and beaver. Muskrat, rabbit, and woodchuck populations are harvested by men. Turkeys are stocked in a few areas.

3.086
New York has the greatest variety of wildlife in the region. A major waterfowl use area is located along the shore of Lake Erie and into the Niagara River (Great Lakes Basin Comm. 1975e). This area is important for waterfowl loafing and feeding during migration and as overwintering area. However, food and cover are poor, the water level fluctuates 4 ft because of Niagara Falls power plants, and there are serious hazards from oil pollution and industrial wastes. There is farm-type wildlife habitat along the lake plain and in the hill country, whereas the upland forests in the Allegheny Plateau provide a high quality habitat for white-tailed deer and occasional black bears and turkeys. Populations of cottontail rabbit, squirrel, and pheasant are harvested by man.

ENDANGERED SPECIES

3.087
Numerous federal- (U.S. Fish Wildl. Serv. 1979) and state-listed (Assoc. Systematics Collec. 1979) endangered, rare, and threatened plant and animal species occur throughout the Lake Erie region. Numerous other species are either recommended for inclusion on the various lists or are under review. Although several fish occur in Lake Erie, there are other fish, mussels, plants, etc., that occur in the inland streams and wetlands. Common habitats for endangered plant species occurring in the Lake Erie region include: shorelines, sand dunes, bogs, islands, peninsulas, vernal pools, swamps, and rock outcrops (Counc. Environ. Qual. 1979).

3.088
Of the federally listed endangered species, two fishes (blue pike and longjaw cisco) could occur in Lake Erie; another fish, the Scioto madtom, and the white cat's paw pearly mussel occur in Ohio streams, the latter primarily in the St. Joseph River (U.S. Fish. Wildl. Serv. 1976). Three birds probably or possibly migrate through the region (peregrine falcon, Kirtland's warbler, and Mississippi sandhill crane), and one bird nests in the region (bald eagle). Two mammals (eastern cougar and Indiana bat) could occur in the region.

3.089
No plant species that occur in the Lake Erie region are currently federally listed as endangered species. However, the northern wild monkshood (<u>Aconitum noveboracense</u>) is listed as threatened in New York and Ohio (U.S. Fish Wildl. Serv. 1978). The Ohio population is located in the Onland Alternative Study Region within Summit and Portage counties, Ohio.

LAND USE

3.090
The major current land uses in the Lake Erie region--cropland, pasture, and forest (U.S. Geol. Surv. 1970)--are shown in Figure 3-2. Most land is privately owned. Large urban areas occur along Lake Erie--notably Buffalo (N.Y.), Erie (Pa.), and Cleveland-Akron (Ohio). Most of the shoreland is currently used for public lands and residential, commercial, and industrial development (Figure 3-3; Int. Joint Comm. 1976). Competition exists for use of the limited undeveloped shoreline for dredge spoil disposal, industrial and residential developments, airport and highway construction, and private vacation homes (Great Lakes Basin Comm. 1974; Int. Joint Comm. 1974). In addition to the

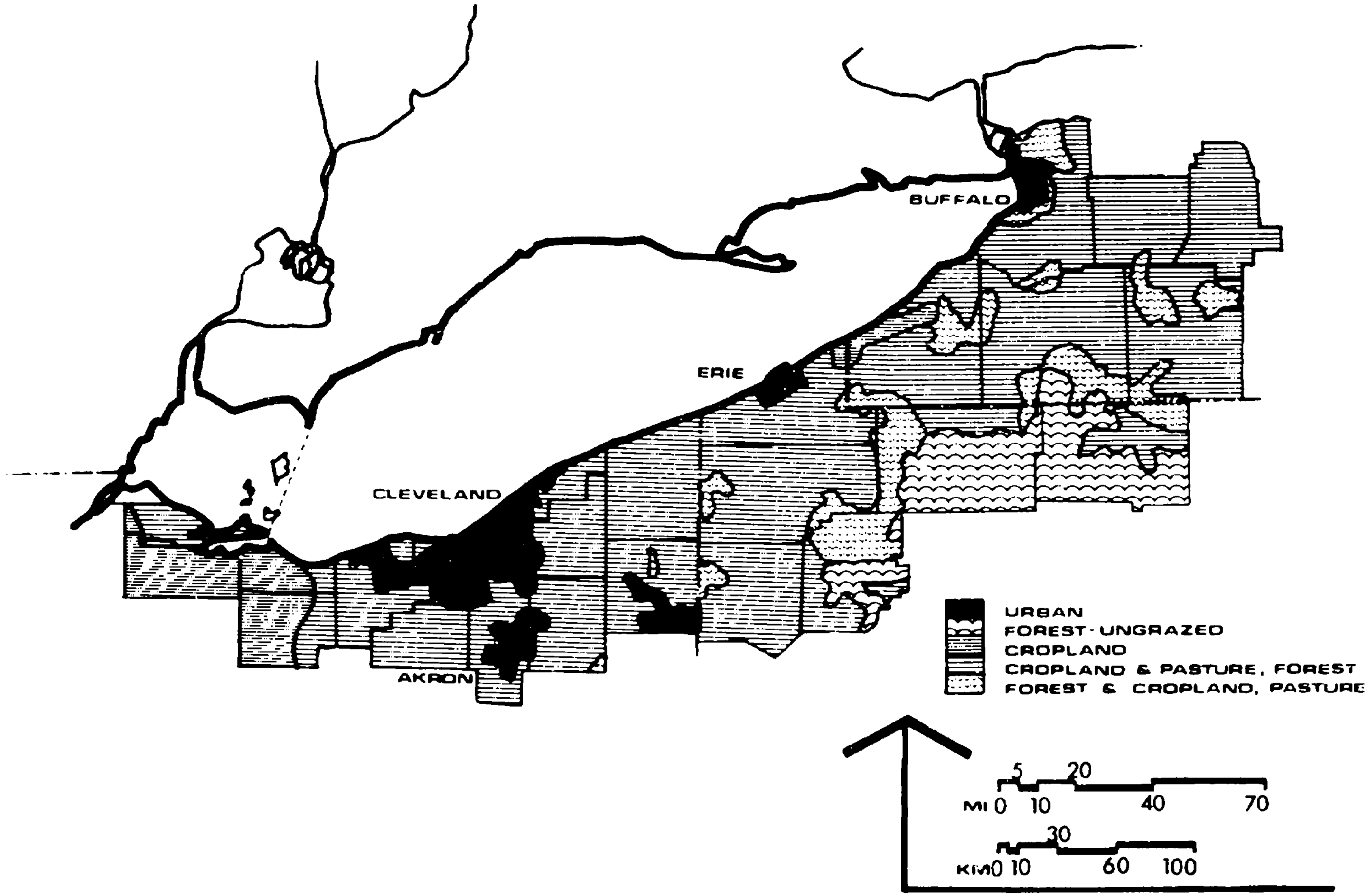

Figure 3-2. Land Use in the Reference Program and Onland Alternative Program Study Regions.

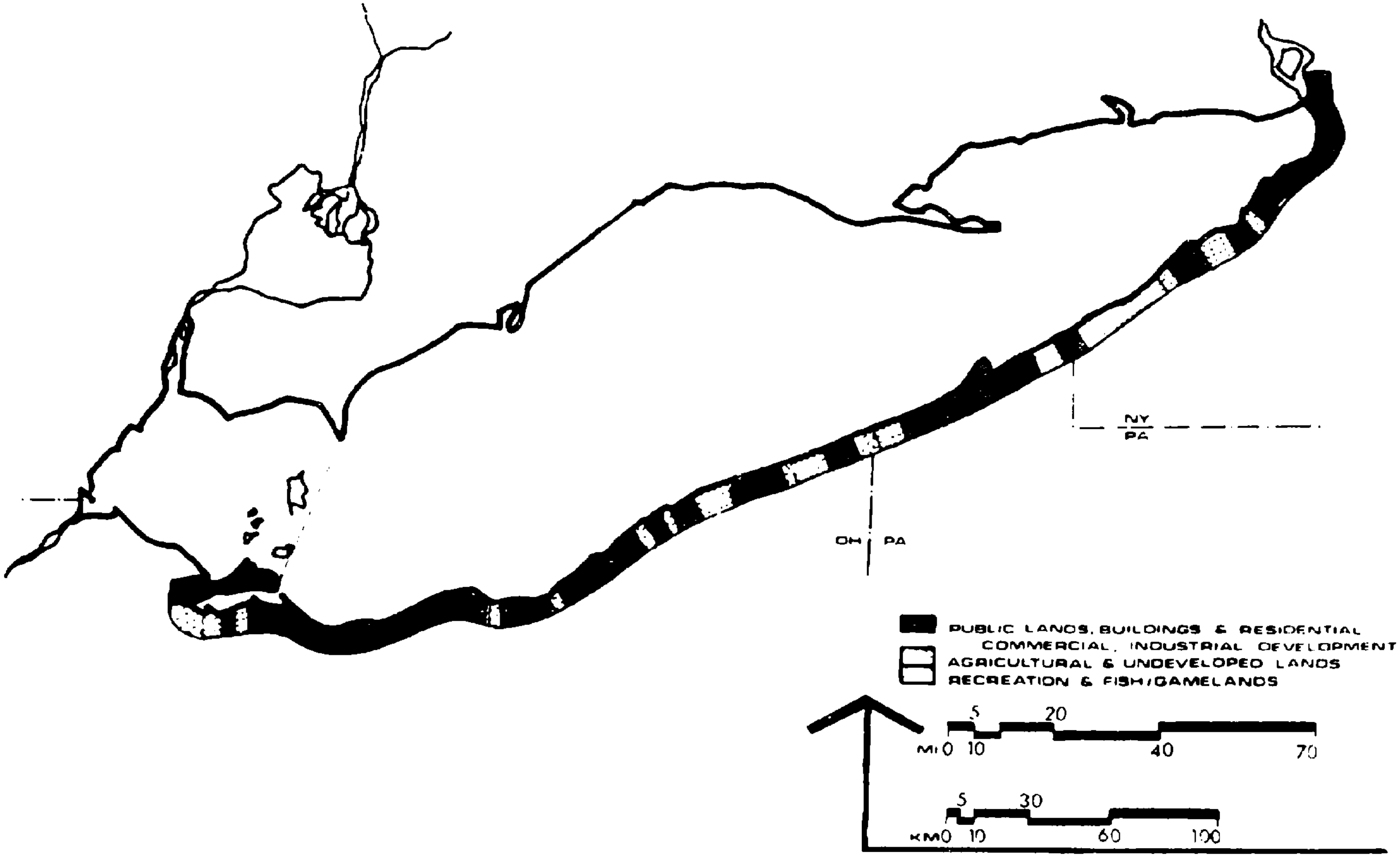

Figure 3-3. Shoreland Uses in the Reference Program and Onland Alternative Program Study Regions.

Coastal Zone Management Act of 1972 (Hildreth 1976; Dinkins 1977; Rubin 1975; Pa. Dep. Environ. Resour. 1978), the permit authority of the Corps of Engineers may become a significant tool in land-use decisions affecting the coastal zone (Great Lakes Basin Comm. 1974). A complex transportation network reflects the heavy urbanization along the Lake and in Ohio.

Urban

3.091
The western part of the region is highly populated and highly industrialized. Land uses are about evenly split between urban, cropland, and forest (Int. Joint Comm. 1976). The human population continues to increase in areas surrounding Cleveland-Akron and along the Lake Erie shoreline. Unfortunately, much of the development along the shore does not take into account the very narrow, extremely erodible shoreline (Int. Joint Comm. 1974; Pa. Dep. Environ. Resour. 1978). In Pennsylvania, it has been recommended that municipalities enact set-back ordinances, which take into account the local bluff recession rate, and avoid using structural techniques that interfere with littoral sediment transport in the Lake. There has been a recent movement of people from urban areas to suburban and rural areas, with a concomitant decrease in cropland and forestland. Zoning conflicts, taxation problems, land value appreciation, and accelerated erosion are commonly associated with this urban growth (Great Lakes Basin Comm. 1974). In the eastern part of the region, about half of the land is forested, one third is cropland, and the remainder is urban land.

3.092
Land disposal of liquid and solid wastes has caused problems in the region. Much suburban land is already used for septic systems. Interest is increasing in applying municipal and industrial wastewater effluents and sludges on open land (Int. Joint Comm. 1974). Solid-waste-disposal areas (landfills) are in much demand and short supply. Although deep-well disposal of industrial waste has not received wide support and has caused serious pollution problems in the past, pressure for such disposal will probably increase as other options are foreclosed. The use of land for waste disposal, if improperly managed, can lead to major land/water pollution problems, and public concern has increased over land/water-use conflicts associated with these activities.

Agricultural

3.093
Much of the farmland in the Lake Erie region is either pasture or idle cropland (Great Lakes Basin Comm. 1974). Dairy and general farming are the most common, with the major crops being hay, corn, soybeans, wheat, oats, fruits, and vegetables. Along the Lake Erie coast, there is some unique farmland used for specialty crops such as apples, peaches, and grapes. These crops rely on the combination of soils and climate that exist near the Lake. Owners of orchard and vineyard lands have been resistant to suburban development pressures (Pa. Dep. Environ. Resour. 1978). About one-fourth of the land in the region is in Soil Capability Classes I and II (Great Lakes Basin Comm. 1974). Although this land is very good for row crops, much of it remains in woodland, pasture, or other uses. As noted under the discussion of soils, erosion is a problem throughout the region for various reasons. Fields in western counties

must be tiled and drained in order to be agriculturally productive. In addition to shoreline erosion, eroded soils have contributed greatly to the turbidity and sedimentation problems in Lake Erie.

3.094
Increasing demands on prime farmland from urban sprawl is causing a major land-use conflict. Official land-use controls (primarily zoning) have not been effective in dealing with this demand. In Pennsylvania, for example, it has been estimated that nearly half of the state's original prime farmlands have been lost to urbanization (Pa. Environ. Qual. Board 1976). It is now state policy to preserve prime farmlands as critical environmental areas. At the federal level, the Soil Conservation Service (SCS), U.S. Department of Agriculture, is responsible for classifying prime and unique farmland and for compiling inventories of these lands. An example of one Reference Program county that has been inventoried is Ashtabula County, Ohio; the SCS survey has identified 249,000 acres of prime farmland and 5000 acres of unique farmland (Roth 1980--personal communication). Other regional inventories are in various degrees of development although, on a site-specific basis, many prime and unique farmland determinations could be made based on soil surveys.

Forest

3 095
Forestlands in the region are not intensively managed or harvested. Hardwoods (oak, hickory, elm, ash, cottonwood, maple, beech, and birch) provide most of the commercial harvest, although some softwoods (pine, fir, and spruce) are harvested in the eastern counties (Great Lakes Basin Comm. 1974). Poor timber harvesting methods and improper woodland grazing often lead to soil erosion and local degradation of surface waters. Almost all commercial forestland is privately owned. There is increasing demand on forestlands for recreational uses, natural areas and preserves, etc. In densely forested Warren and McKean counties, the state considers the watersheds to have high quality streams and discourages those land-use activities that could degrade these watersheds (Pa. Environ. Qual. Board 1976).

Recreational

3.096
The regional recreational land-use patterns developed from two resources: (1) the natural amenities of the Lake Erie shoreline and stream valleys, and (2) the demand for recreation facilities near urban populations. Additionally, the relative lack of inland lakes and streams has placed increasing pressure on access to Lake Erie for recreation (Int. Joint Comm. 1976). The third largest item in the Ohio recreation budget is Lake Eri· beach acquisition and development (Ohio Dep. Nat. Resource. 1975). In Pennsylvania, the bluffs are often 120-ft high, with the only points of easy lake access being via stream valleys. New York considers the development of shorelines, with degradation of the view from the water and restriction of public access, to be a critical problem (N.Y. State Parks Rec. 1972).

3.097
The shoreline has been utilized as the prime element of water recreation facilities (boating, swimming, fishing, etc.) and as an attractive background for traditional onland recreation (golf courses, amusement parks, athletic

fields, etc.). Development of recreation facilities has been greatest in large urban areas. Governments and private enterprise have developed facilities to meet growing demands. Man-made lakes and resources have provided additional settings for recreational activities and related businesses.

AIR QUALITY

Air Pollution Sources and Ambient Conditions

3.098
The U.S. Environmental Protection Agency has promulgated standards for seven pollutants. These standards are defined as the National Ambient Air Quality Standards (NAAQS) and the pollutants are referred to as the criteria pollutants (Table 3-9). The NAAQS are divided into primary and secondary standards. Primary standards are established at a level to give an adequate margin of safety for the protection of public health. Secondary standards are established at levels that are determined requisite for the protection of the public welfare from any known or anticipated adverse effects resulting from the presence of air pollutants (USEPA 1971). Ambient air quality standards

Table 3-9. National Ambient Air Quality Standards[a]
($\mu g/m^3$ at 25°C, 760 mm pressure)

	Primary Standard		Secondary Standard	
Pollutant	Annual Mean	Maximum Concentration (Allowed Once Yearly)	Annual Mean	Maximum Concentration (Allowed Once Yearly)
Sulfur oxides (measured as SO_2)	80	365 (24-h avg.)	--	1300 (3-h avg.)
Total suspended particulates	75	260 (24-h avg.)	60	150 (24-h avg.)
Carbon monoxide	--	10,000 (8-h avg.) 40,000 (1-h avg.)	Same as primary	--
Photochemical oxidants (measured as ozone)	--	240 (1-h avg.)	Same as primary	--
Hydrocarbons	--	160 (3-h avg., 6-9 a.m.)	Same as primary	--
Nitrogen dioxide	100	--	Same as primary	--
Lead	--	1.5 (quarterly avg.)	Same as primary	--

[a]Source: 40 CFR 50.

promulgated by the states must be at least as stringent as the NAAQS. Major sources for the criteria pollutants are as follows (Stern 1976; Ohio Environ. Prot. Agency 1977):

Total suspended particulates (TSP)
- Industrial processes (e.g., steel making and grain handling)
- Electric power generation
- Fugitive dust (e.g., unpaved roads and open land)

Sulfur dioxide (SO_2)
- Stationary source fuel combustion
- Industrial processes (e.g., smelting)

Nitrogen oxides (NO_x as nitrogen dioxide)
- Transportation (internal combustion engines)
- Stationary source fuel combustion

Hydrocarbons (HC)
- Transportation (internal combustion engines)
- Processing and marketing petroleum products

Photochemical oxidants (ozone - O_3)
- Photochemical oxidants are secondary pollutants (not emitted directly to the atmosphere) which are formed through a wide variety of photochemical reactions. Precursor pollutants include nitrogen oxides and hydrocarbons.

Lead (Pb)
- Lead smelting
- Transportation (internal combustion engines)

Carbon Monoxide (CO)
- Transportation (internal combustion engines)
- Industrial process losses

3.099
Air quality data collected in Ohio, Pennsylvania, and New York during 1977 are used to give a relative indication of air pollution levels for the Lake Erie shoreline and adjacent counties in those states (Ohio Environ. Prot. Agency 1977; Pa. Dep. Environ. Resour. 1977; N.Y. Dep. Environ. Conserv. 1978). The air quality data summary information for these states is biased to the urban/industrial setting. This is a reflection of the large proportion of monitoring stations sited in developed areas.

3.100
Ohio air quality data show violations of the annual and 24-hour secondary NAAQS for TSP occurring in most lakeshore and adjacent counties. Exceptions to this are annual TSP levels in nonmetropolitan areas of Cuyahoga and Geauga counties which averaged about 56 $\mu g/m^3$. Annual average SO_2 levels are within primary standards in affected counties. However, violations of the short-term (3-hour and 24-hour) standard were recorded in metropolitan Cleveland, Lake and Lorain counties. The annual NO_2 standard was not exceeded at any monitoring site in affected counties. However, 24-hour averages in excess of

150 $\mu g/m^3$ were recorded in Lorain and Cuyahoga counties. Metropolitan areas of Cleveland and Akron showed violation of the 8-hour CO standard. The 1-hour photochemical oxidant standard (measured as ozone) was exceeded in all of the affected counties. Neither hydrocarbons nor lead were measured in the affected counties during 1977.

3.101
Pennsylvania air quality data for Lake Erie shoreline and adjacent counties consists exclusively of data gathered in the city of Erie and its surroundings. The TSP data collected on monitors located within the urban Erie area show violations of secondary annual and 24-hour NAAQS, whereas stations in outlying areas are in attainment of standards. The SO_2 monitoring was not conducted in the affected area in 1977. No statement can be made about NO_2 levels since less than 10% of the data base consists of valid observations for the year. Hydrocarbon measurements showed an average hourly value of 319 $\mu g/m^3$ with only 15.9% valid observations for the year. Hourly average ozone levels were measured at about 52 $\mu g/m^3$, with 77 violations of the NAAQS. The hourly average CO values were within the NAAQS 1-hour standard. No measurements for lead were made during the year.

3.102
The New York state air quality monitoring effort for Lake Erie shoreline and adjacent counties is concentrated in relatively industrialized Erie and Niagara counties. In these counties, the annual average primary NAAQS for TSP was exceeded at ten monitoring sites, and the 24-hour standard was exceeded at four sites. Neither short-term nor annual average SO_2 standards were exceeded at any monitors in these two counties. Levels of NO_2 were well within the annual NAAQS for this relatively industrial area. At a single monitoring site in Buffalo, the NAAQS for oxidants was exceeded seven times. Carbon monoxide levels were well within standards for these counties. Monitoring effort in less industrialized counties in the affected area (Chautauqua, Cattaraugus, and Allegany counties) is less intense; ozone, NO_2, and CO were not monitored in 1977. Monitoring for TSP and SO_2 showed no violation of standards.

Air Quality Goals

3.103
For areas that are not attaining NAAQS, state implementation plan revisions must impose controls on both new and existing sources sufficient to demonstrate attainment of the ambient standard as expeditiously as practicable. In the case of primary standards, attainment must be achieved by no later than December 31, 1982. A possible extension through 1987 is available for areas unable to meet the primary oxidant and/or CO standard by the 1982 deadline (U.S. Congress 1977). Attainment of secondary standards, as defined under the 1970 Clean Air Act amendments, must be accomplished within a reasonable time. The definition of "reasonable time" (1977 amendments, Section 172) depends on the degree of emission reduction needed and on the social, economic, and technical constraints involved with executing an attainment strategy to meet secondary standards. Where only reasonably available control technology is needed for attainment of secondary standards, the attainment deadline is December 31, 1982 (Raffle 1979).

ESTHETIC ENVIRONMENT

Introduction to Prototype Settings

3.104
Five prototypical environmental settings (adapted from the Great Lakes Basin Commission's (1975d) anthropomorphic land-use classification system) that are representative of typical lake and watershed use activities have been developed to facilitate evaluation of esthetic impacts from Reference Program activities. Each prototype setting presented includes a description of general environmental setting, structure of activity, and associated user groups. The five prototype esthetic settings represent the broad spectrum of esthetic values that may be experienced in the Reference Program Study Region and are useful in establishing a structure for evaluation of esthetic impacts in the absence of site-specific development proposals.

Description of Prototype Settings

Prototype Setting No. 1: Urban/Industrial

3.105
The urban/industrial setting includes areas of high-intensity onshore industrial activity often coupled with port facilities and commercial navigation, e.g., electric generating plants, factories and warehouses, and spoil disposal areas (Figure 3-4). Particular shore structures in this setting might include groins, jetties, breakwaters, bulkheads, spoil islands, intake and outflow pipes, dredges, and power and fuel transmission lines. Of the approximately 290 miles of Lake Erie shore, 69 miles are devoted to industrial, commercial, or public land facilities and associated activities (Great Lakes Basin Comm. 1975d).

3.106
Potential user groups include the commercial boater and factory worker. Because of the existing commercial elements, esthetic character of the setting is generally the poorest of any of the Lake Erie shoreline settings. User groups within this setting are generally not anticipating views possessing particularly good esthetic quality. Aside from unique historic or cultural landmarks, views to and from the industrial setting are rarely valued for their esthetic quality.

Prototype Setting No. 2: Residential

3.107
Low-density shore residence settings occur extensively along the Lake Erie shoreline (Figure 3-5). Approximately 227 miles of shoreline are expected to be dedicated to residential development by the year 2000 (Great Lakes Basin Comm. 1975d). Prominent elements of this setting include low-density housing developments adjacent to the lakefront, small marinas useful for protection of recreational boats, and beaches large enough for the residents' use.

3.108
The average participant in this setting is not a visitor or part-time user but has a personal stake in the setting due to land and property ownership and full-time use of the environment. Framed viewsheds of the Lake and shoreline

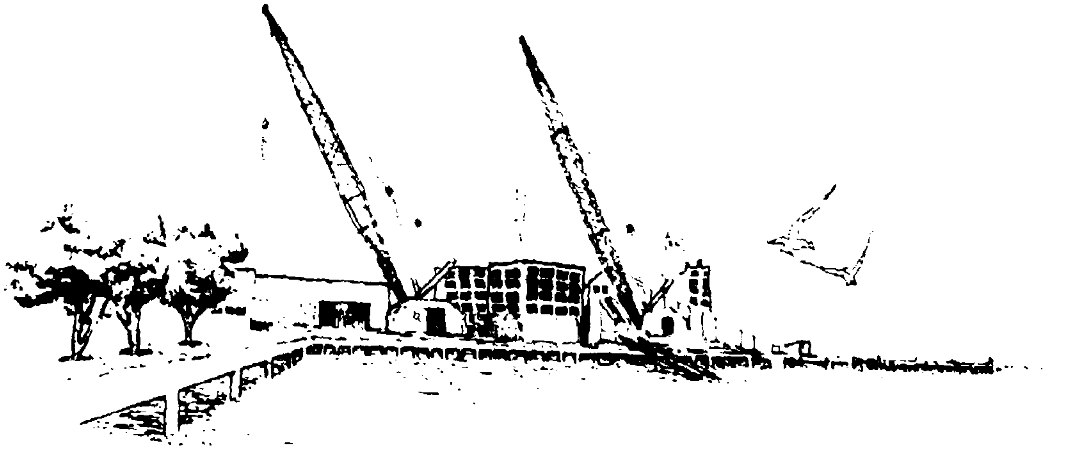

Figure 3-4. Prototype Setting No. 1: Urban/Industrial.

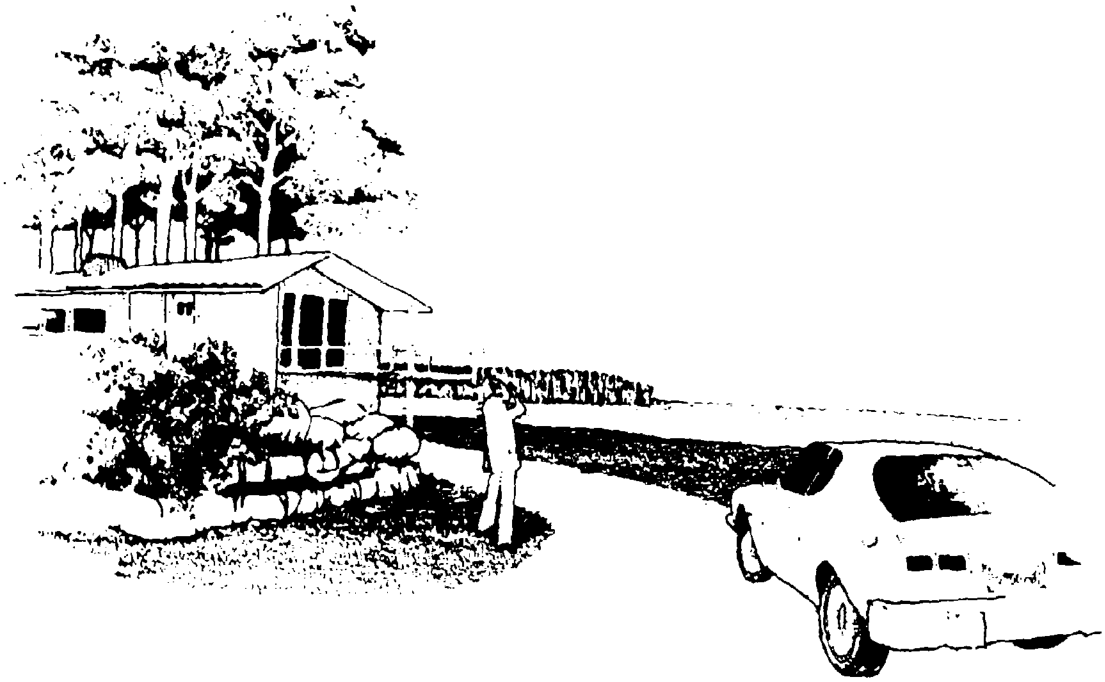

Figure 3-5. Prototype Setting No. 2: Residential.

from within the home are often used for gaining economic leverage in promoting real estate sales. Other desirable esthetic attributes include viewsheds containing extensive undisturbed shoreline, historic areas or landmarks, lake tributaries, and undisturbed riparian or marshland habitat.

Prototype Setting No. 3: Open Water

3.109
The open water setting includes all lake surfaces not associated with surrounding land areas (more than 0.5 mile from shore). Settings of this nature are sought by recreational boaters and some commercial fishermen. The often sterile and isolated character of the "open sea" is a unique recreational setting afforded only to those engaged in boating activities. The only natural elements forming this setting are water, views of the horizon line and distant shore edge, and sky (Figure 3-6).

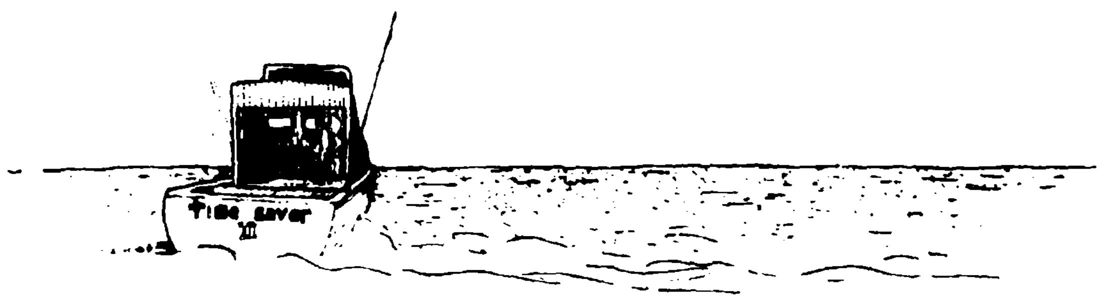

Figure 3-6. Prototype Setting No. 3: Open Water.

Prototype Setting No. 4: Multi-Use Recreation

3.110
High-intensity recreational use of the more than 1300 acres of beach along the western and southern shores of the Lake occurs during May through October (Figure 3-7). Its climate makes Lake Erie the most desirable of the Great Lakes for water sports. Major viewsheds to and from the beach environment include beachfront, beachfront parks and complimentary facilities (e.g., bathhouses, parking areas, shops, miniature golf courses, food stands, and beach erosion-control devices such as jetties and groins), and small-scale harbor and docking facilities that often show signs of congestion during peak recreational periods.

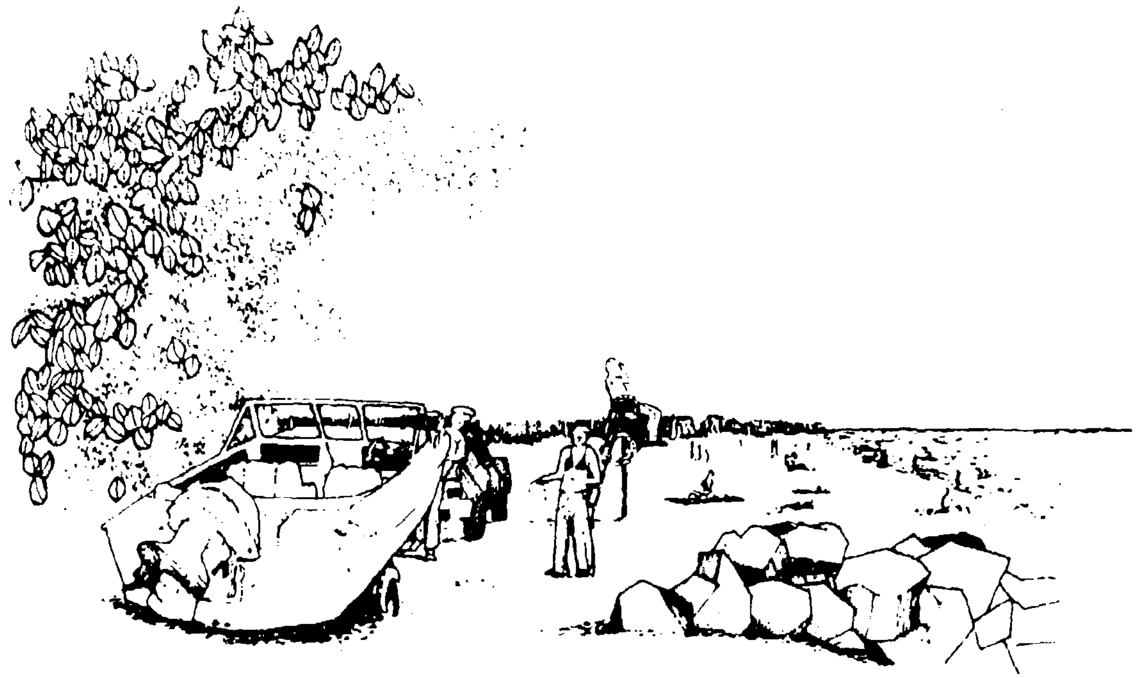

Figure 3-7. Prototype Setting No. 4: Multi-Use Recreation.

3.111
The major user groups included in this setting are picnickers, swimmers, and sunbathers. Other activities occurring throughout the lake/lakeshore interface (< 0.5 mile from shore) are pleasure boating, sport fishing, and water skiing.

Prototype Setting No. 5: Natural Areas

3.112
Wetland areas (marshes, swamps, riparian stream corridors), wildlife habitats, nature preserves, sand dunes, undeveloped forests, inland lakes, and natural bluffs are all possible viewshed elements of the natural area setting (Figure 3-8). Lake Erie's shoreline contains highly productive marshes, shoals, and stream corridors; the majority of natural areas around Lake Erie are wetland areas, which are considered highly sensitive to alteration.

3.113
Hunters, fishermen, and nature observers all anticipate viewsheds completely void of man's encroachment. The naturalness or lack of man-made entities such as buildings, roads, or other structures render this type of setting most vulnerable to esthetic degradation.

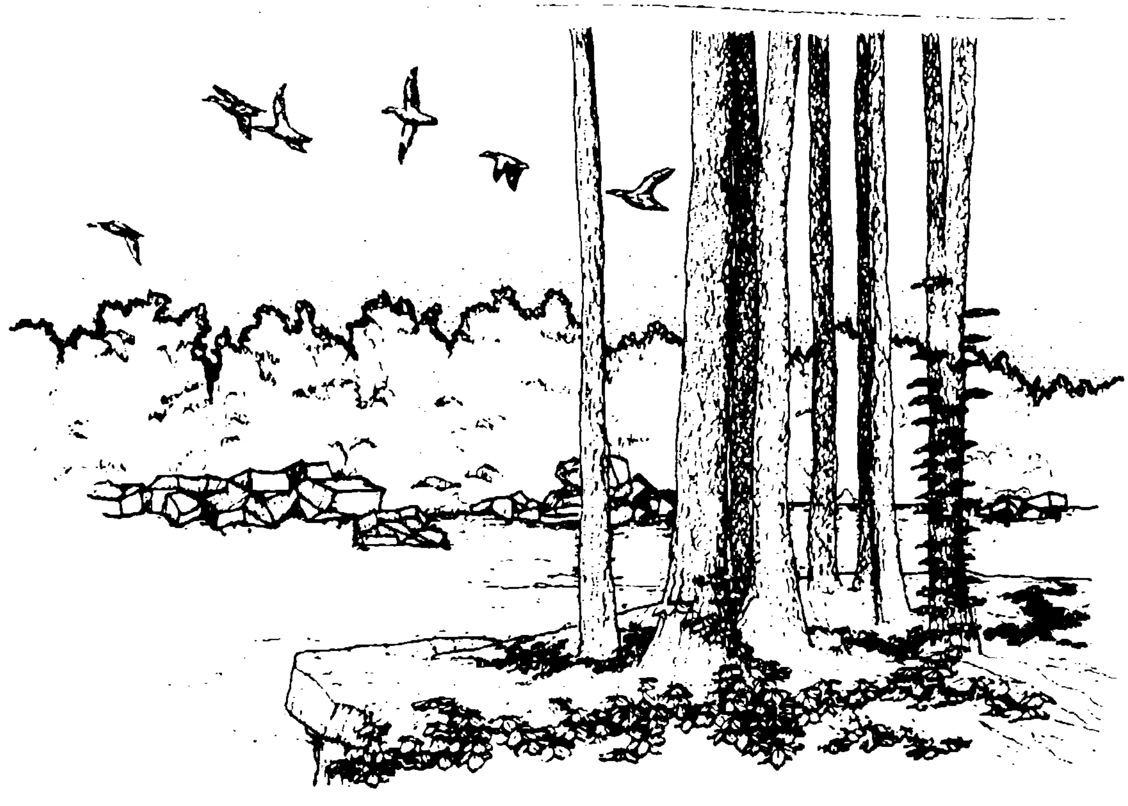

Figure 3-8. Prototype Setting No. 5: Natural Areas.

CULTURAL RESOURCES

3.114
Cultural resources exist from historic and prehistoric occupations that were present throughout the Lake Erie region. Perhaps as early as 10,000 B.C., small bands of hunters and gatherers occupied parts of what is now the Lake Erie Basin. Environmental changes occurred throughout this area as the glacier retreated and the technological and economic patterns of the hunting-gathering groups made adaptive responses to these changes. Although regional environmental characteristics remained about the same after 5000 B.C., the sociocultural organization of local groups became more complex, group size increased, and settlement became more permanent. Adoption of Meso-American domesticates and maize-based horticulture gradually decreased dependence on hunting/gathering activities. By the 18th century, a number of tribally organized groups unified politically, forming several confederacies, and European explorers and traders came into the area. With time, trade-related settlements, forts, and homesteads were located throughout the area. Evidence of prehistoric and historic occupations are expected to be represented by a variety of surface and subsurface material remains located onshore and on the submerged lake bottom.

3.115
A cultural resource study currently is being conducted in the Reference Program Study Region, including the lake bottom and one-mile inland from the lakeshore. The purpose of this study is to: (1) locate and evaluate known cultural resource sites, (2) assess the probabilities for unknown sites and (3) establish guidelines for the reconnaissance and protection programs in areas that might be developed for gas production. A multidisciplinary approach has been taken for collections and analyzation, including archeology, ethnology, history, paleoecology, and appropriate field methodologies. Available information on site locations and historic events are the basis for modeling the locations of other sites in areas where data are absent. Predictive models are based on behavioral reconstructions of past lifeways and the processes involved in their evolution. The utility of the model for predicting site locations by period and possible function and the recommended guidelines for field methods will be field tested in a limited study area.

SOCIOECONOMICS

Population

3.116
Population densities vary within the Reference Program Study Region. High population concentrations are located around Buffalo, New York and Cleveland, Ohio (Figure 3-9). The remaining area adjoining the Lake has a more sparse settlement pattern.

3.117
It has been estimated that the Reference Program Study Region will have a 1980 population of approximately 4 million people (Table 3-10). The population in the region increased 6.6% from 1960 to 1970, then decreased 1.1% since 1970, based on 1975 estimates. A modest population increase (1.2%) from 1975 to 1980 has been projected. From 1980 to 1990 the projected growth rate is 7.8%.

New York

3.118
The population and density in Chautauqua County is low (Table 3-10). This county has lagged behind New York State and the United States in percent of population increase for the past five decades. The 1970 Census found that the population increased only by 1.3% over 1960 figures. The census classified 54.8% of the population as urban, 38.9% as rural nonfarm, with the remaining 6.3% as farm population. The towns, villages, hamlets, and the City of Dunkirk which border on Lake Erie are considered the Erie Lake Plain. Only 37.1% of the county's population lived in this area in 1970 (Chautauqua Co. Plan. Board and Dep. Plan. 1973). Population growth in the area has decreased markedly over the past decades, from a +10% increase between 1950 and 1960 to less than 1% during the 1970s.

3.119
Erie County's population has increased only by 5.5% since 1960. A significant redistribution has occurred in the county during this time. The city of Buffalo experienced a 19% decline in population, whereas suburban towns adjacent to the city absorbed this population. Most of the county's future growth will be in suburban and rural areas. Projected growth rates are more moderate

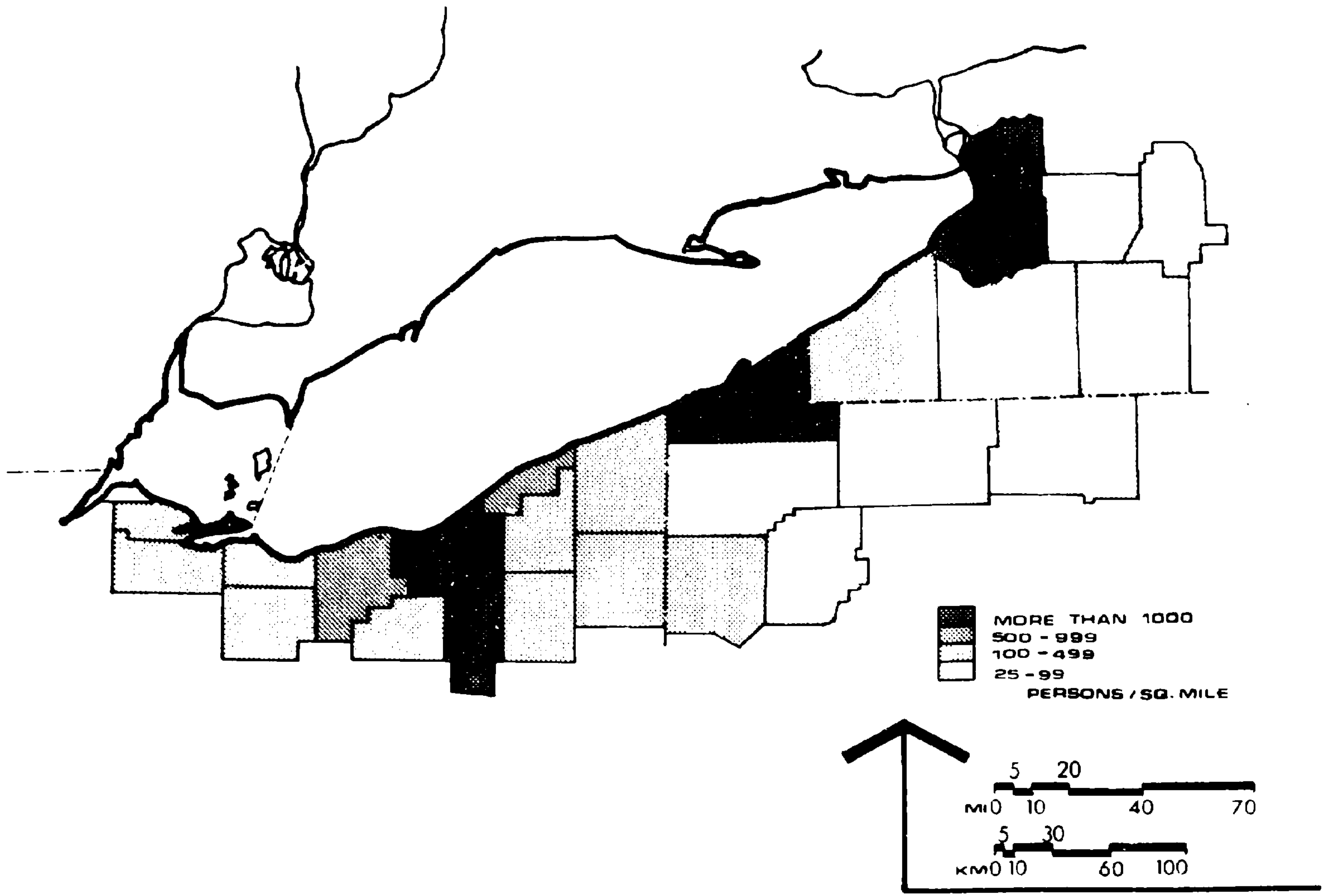

Figure 3-9. Population Density in the Reference Program and Onland Alternative Program Study Regions.

Table 3-10. Estimated and Projected Population of the Reference Program Study Region

County	1960	1970	Estimated 1975 Total	Estimated 1975 Persons/mi^2	Projected 1980	Projected 1990
New York						
Chautauqua	145,377	147,305	147,392	136	148,791	155,947
Erie	1,064,688	1,113,491	1,123,400	1030	1,147,221	1,214,484
Pennsylvania						
Erie	250,682	263,654	273,396	336	284,037	307,505
Ohio						
Ashtabula	93,067	98,237	101,940	146	n.a.	126,826
Cuyahoga	1,647,895	1,721,300	1,603,900	3493	1,556,000	1,594,000[a]
Erie	68,000	75,909	77,327	293	97,958	126,112
Lake	148,700	197,200	206,881	896	218,900	255,400
Lorain	217,500	256,843	286,497[a]	543	293,501	370,009
Ottawa	35,323	39,272	39,482	149	42,428	50,075
Sandusky	56,486	60,983	69,500	154	72,000	90,000

[a]"High" estimates of high-low projection.

n.a. = data not available.

Sources: Erie and Niagara Counties Regional Planning Board (1975); Chautauqua County Planning Board (1978); Ashtabula County Planning Commission (1977); Cuyahoga County Regional Planning Commission (1976); Erie Regional Planning Commission (1970); Lorain County Regional Planning Commission (1973); Toledo Metropolitan Area COG (undated--information supplied by Lake County Planning Commission); Sandusky County Planning Commission (undated); Erie County Metropolitan Planning Commission (1977); Erie County Department of Planning and Erie County Metropolitan Planning Commission (1978); U.S. Bureau of the Census (1977).

than those experienced in the past (Erie and Niagara Counties Regional Planning Board 1977). The slower growth rate for the county will be a result of the out-migration and a declining birth rate (Erie and Niagara Counties Regional Planning Board 1976).

Pennsylvania

3.120
Erie County's population has and continues to increase slowly. The location of high concentrations of residences is directly correlated to availability of sewer and water facilities. Since most of these facilities are located in lakeside municipalities, population growth will continue to be in these communities (Erie County Metropolitan Planning Commission 1977).

3.121
Erie County's coastal zone was estimated to have a 1975 population of 214,868 which accounts for 80.2% of the county's population. The coastal zone is comprised of 15 minor civil divisions, including the city of Erie and its adjoining suburbs. The coastal zone is expected to reach about 250,000 by the turn of the century (Erie Metropolitan Planning Department 1975).

3.122
Construction of a proposed iron and steel manufacturing complex in northwestern Pennsylvania (U.S. Stee. Conneaut Plant) would increase the county's population; about 5000 of the anticipated in-migrants would reside in the county (U.S. Army Engineer District, Buffalo-B, undated).

Ohio

3.123
The number of people per square mile in the seven counties bordering Lake Erie varies from a low of 146 people to a high of about 3500 people (Table 3-10). Thus, the character of these Ohio counties ranges from being primarily rural to metropolitan.

3.124
Except for Cleveland (Cuyahoga County), which is facing a population decline, the area has experienced steady growth in residents. The size of the area and resources available (access to water, highway and rail transportation and proximity to coal producing areas) suggest that the region has not yet reached its full potential growth rate. The large coastal area draws many transient people to the region to enjoy seasonal recreation facilities.

Regional Economy

Industrial Profile

3.125
New York, Pennsylvania, and Ohio are among the most important industrialized states in the nation. In terms of value added by manufacturing, New York ranks second in the nation ($38.8 billion), Ohio third ($37.7 billion), and Pennsylvania sixth ($32.2 billion) (1976 data from U.S. Bur. Census 1978b).

3.126
The regional economy is dominated by manufacturing. Employment in manufacturing in every county exceeds the national average by significant margins; the average for the 10 counties is 44%, compared to a national average of approximately 30% (1977). In two Ohio counties, Lorain and Sandusky, manufacturing employment exceeds 50%.

3.127
The Reference Program Study Region serves as a major transshipment area where Appalachian coal meets Mesabi or imported iron ore. Thus, primary metal industries (the production of iron and steel) are important and basic components of the regional economy, employing more than 54,000 people. Industries that use steel in the manufacturing process (fabricated metal products) are, however, the most important group of industries, employing more than 72,000 employees, or 14% of the total employment in manufacturing. Other major industries in the region include machinery (>68,000 employees) and transportation equipment (>31,000); both are important users of steel (Table 3-11).

3.128
Trends in manufacturing (Table 3-12) have important implications for the economic well-being of the Reference Program Study Region. Between 1972 and

Table 3-11. Economic Profile of the Reference Program Study Region

Geographic Division	Number of Employees	Major Sectors of the Economy: Description	Major Sectors of the Economy: Percentage of Total Employment in 1977	Major Industrial Activity[a]: Description	Major Industrial Activity[a]: No. of Employees in 1972
PROFILE BY COUNTY[b]					
New York					
Chautauqua	37,682	Manufacturing	43	Fabricated metal products	3,600
		Wholesale, retail trade	27	Machinery, except electrical	3,100
		Services	18	Food and kindred products	2,200
				Furniture and fixtures	2,100
				Primary metal industries	1,600
Erie	331,872	Manufacturing	33	Primary metal industries	19,900
		Wholesale, retail trade	29	Fabricated metal products	13,200
		Services	22	Machinery, except electrical	10,800
				Food and kindred products	9,500
				Electric and electronic equipment	7,400
Pennsylvania					
Erie	92,918	Manufacturing	45	Fabricated metal products	5,800
		Wholesale, retail trade	22	Machinery, except electrical	5,500
		Services	20	Electric and electronic equipment	3,600
				Primary metal industries	3,500
				Rubber, misc. plastic products	3,500
Ohio					
Ashtabula	25,328	Manufacturing	49	Fabricated metal products	2,700
		Wholesale, retail trade	21	Rubber, misc. plastic products	2,300
		Services	14	Electric and electronic equipment	1,700
				Chemicals and allied products	1,300
Cuyahoga	653,995	Manufacturing	36	Fabricated metal products	37,000
		Wholesale, retail trade	26	Machinery, except electrical	36,400
		Services	22	Transportation equipment	30,300
				Primary metal industries	28,500
				Electric and electronic equipment	19,600
Erie	26,391	Manufacturing	45	Machinery, except electrical	3,000
		Wholesale, retail trade	25	Rubber, misc. plastic products	1,200
		Services	18	Primary metal industries	1,200
Lake	56,121	Manufacturing	47	Machinery, except electrical	4,900
		Wholesale, retail trade	27	Fabricated metal products	3,100
		Services	13	Rubber, misc. plastic products	1,400

Table 3-11. Continued

Geographic Division	Number of Employees	Major Sectors of the Economy: Description	Percentage of Total Employment in 1977	Major Industrial Activity[a]: Description	No. of Employees in 1972
Lorain	78,488	Manufacturing	53	Fabricated metal products	6,700
		Wholesale, retail trade	20	Machinery, except electrical	3,900
		Services	16	Chemicals and allied products	1,100
				Rubber, misc. plastic products	1,000
Ottawa	8,011	Manufacturing	37	Transportation equipment	969
		Wholesale, retail trade	26	Machinery, except electrical	547
		Services	12		
Sandusky	16,850	Manufacturing	52	Food and kindred products	1,100
		Wholesale, retail trade	23	Stove, clay, glass products	800
		Services	13	Rubber, misc. plastic products	600
		PROFILE BY SMSA[c]			
New York					
Buffalo	397,279	Manufacturing	36	Primary metal industries	22,200
		Wholesale, retail trade	28	Machinery, except electrical	20,000
		Services	21	Fabricated metal products	14,300
				Food and kindred products	10,800
Pennsylvania					
Erie	92,918	Manufacturing	45	Fabricated metal products	5,800
		Wholesale, retail trade	22	Machinery, except electrical	5,500
		Services	20	Electric and electronic equipment	3,600
				Primary metal industries	3,500
				Rubber, misc. plastic products	3,500
Ohio					
Cleveland	744,818	Manufacturing	37	Machinery, except electrical	42,500
		Wholesale, retail trade	26	Fabricated metal products	41,500
		Services	21	Transportation equipment	31,700
				Primary metal industries	29,600

Table 3-11. Continued

Geographic Division	Number of Employees	Major Sectors of the Economy: Description	Major Sectors of the Economy: Percentage of Total Employment in 1977	Major Industrial Activity[a]: Description	Major Industrial Activity[a]: No. of Employees in 1972
			PROFILE BY STATE[b]		
New York	5,520,754	Manufacturing	27	Electric and electronic equipment	161,300
		Services	26	Machinery, except electrical	135,200
		Wholesale, retail trade	25	Instruments, related products	96,400
				Fabricated metal products	93,500
Pennsylvania	3,733,804	Manufacturing	36	Primary metal industries	194,500
		Wholesale, retail trade	24	Machinery, except electrical	122,700
		Services	21	Electric and electronic equipment	116,500
				Fabricated metal products	108,400
Ohio	3,454,009	Manufacturing	39	Machinery, except electrical	198,500
		Wholesale, retail trade	26	Fabricated metal products	156,500
		Services	19	Primary metal industries	146,200
				Electric and electronic equipment	110,200
United States	64,975,580	Manufacturing	30	Machinery, except electrical	1,827,700
		Wholesale, retail trade	27	Transportation equipment	1,719,000
		Services	22	Electric and electronic equipment	1,661,300
				Food and kindred products	1,569,300
				Fabricated metal products	1,493,300

[a]Data from U.S. Bureau of the Census (1976): pp. 33-11, 33-24, 33-35, 33-36, 36-11, 36-20, 36-25, 36-29, 36-30, 36-31, 36-33, 36-34, 36-35, [illegible], 39-20.

[b]Data from U.S. Bureau of the Census (1979b): New York, pp. 1, 44, 61; Pennsylvania, pp. 1, 99; Ohio, pp. 1, 29, 53, 67, 111, 120, 156, 169.

[c]Data from U.S. Bureau of the Census (1978a): pp. 36, 48, 68.

Table 3-12. Trends in Manufacturing in New York, Pennsylvania, and Ohio, 1972-1977[a]

State/County	Number of Manufacturing Establishments (20 employees or more) 1972	1977	% Change
New York			
Chautauqua	112	105	-6.2
Erie	525	502	-4.4
Pennsylvania			
Erie	203	207	1.9
Ohio			
Ashtabula	77	76	-1.3
Cuyahoga	1370	1355	-1.1
Erie	63	59	-6.3
Lake	142	172	21.1
Lorain	110	123	11.8
Ottawa	23	22	-4.3
Sandusky	53	53	0

[a]Data from U.S. Bureau of the Census (1979a).

1977, three counties--Lake and Lorain, Ohio, and Erie, Pennsylvania--experienced growth in the number of manufacturing establishments (with 20 employees or more). Lake and Lorain experienced significant increases in the number of industries (21 and 12%, respectively) locating within these two counties. However, seven of 10 counties in the Reference Program Study Region either had no growth or experienced actual declines in the number of manufacturing establishments. Both Erie, Ohio, and Chautauqua, New York, had declines exceeding 6%. In the five-year period 1972-1977, more than 50 manufacturing establishments (with 20 employees or more) either closed or moved out of the area. These data suggest that with the exception of the greater Cleveland area (excluding Cuyahoga County), the Reference Program Study Region is not an area of industrial growth; rather, manufacturing is declining in importance in most of the counties of the region.

3.129
Industries within the region are highly interdependent upon production from other regional manufacturers. The transportation industry, for example, relies upon steel producers for its raw materials and purchases products from rubber and plastic manufacturers and from electrical and electronic equipment industries. Fabricated metal producers purchase steel as a raw material and in turn produce finished products purchased by the transportation industry. Any significant decline in the production of any major industry will have an adverse economic impact upon the regional economy.

Industrial Natural Gas Consumption

3.130
Many of the major manufacturers in the Lake Erie region are gas-intensive industries. Natural gas is used primarily in the manufacturing process, or as a feedstock. In iron and steel production, for example, gas is used in coking and smelting furnaces, to maintain high temperatures during the production of steel, and as a reheating agent (to reheat ladles, for example). In the chemicals and allied products industry, gas is used as a feedstock. For many manufacturers in the Lake Erie region, an adequate and uninterrupted supply of natural gas is a prerequisite for the production process. Plants and equipment have been built and designed to use natural gas, and other energy sources could not be used without extensive retrofitting or investments made in new plants and equipment.

3.131
The importance of natural gas to the Lake Erie region and to specific industries was identified in the issues examination report (McGregor et al. 1978) that preceded this environmental impact statement.

3.132
Within the Reference Program Study Region, Ohio consumed more natural gas than Pennsylvania and New York combined (Table 3-13). This was the result of the extent of Ohio's Lake Erie shoreline and the industrial dominance of the Cleveland area (Cuyahoga County). Cuyahoga County consumed 48% of the total

Table 3-13. Projected Natural Gas Consumption and Curtailments by County and Major Industrial Group for the Reference Program Study Region, April 1977-March 1978[a]

County	Natural Gas (MCF)[b]		SIC[c]	Major Industrial Group	Natural Gas (MCF)[b]	
	Deliveries	Curtailments			Deliveries	Curtailments
New York						
Erie	18,170,628	0	33	Primary metal	10,841,554	0
Chautauqua	2,918,247	0	33	Primary metal	1,250,100	0
Total	21,088,875	0			12,091,654	0
Ohio						
Cuyahoga	48,585,836	1,002,806	33	Primary metal	33,429,598	617,482
Lorain	9,462,107	2,106,077	33	Primary metal	6,690,350	618,974
Lake	4,241,904	174,203	28	Chemicals, allied products	2,889,246	55,993
Ashtabula	4,229,718	139,279	28	Chemicals, allied products	1,915,685	95,984
Sandusky	3,334,721	1,542,328	32	Stone, clay, glass, concrete	1,702,340	138,396
Erie	2,946,883	1,007,879	32	Stone, clay, glass, concrete	1,120,202	144,710
Ottawa	2,023,130	425,193	32	Stone, clay, glass, concrete	1,443,695	74,306
Total	74,824,299	6,397,765			49,191,116	1,745,845
Pennsylvania						
Erie	4,585,582	40,044	33	Primary metal	2,907,776	0
Total	4,585,582	40,044			2,907,776	0
Total				Total		
10-County Study Area	100,498,756	6,437,809		Major Industrial Groups	64,190,546	1,745,845

[a]These projections (McGraw-Hill 1978), based on the most current information available at the time of the Phase I report preparation (McGregor et al. 1978), have been treated as actual data in the text for the purpose of readability and have not yet been updated to "reported data" status.

[b]MCF = thousands of cubic feet. To convert cubic feet to cubic meters, multiply by 0.02832.

[c]SIC = Standard Industrial Classification.

gas deliveries to the study area. Industries in the Ohio counties consumed 74% of the total 100.5 BCF of gas consumed by all large end-users in the region.

3.133
Five groups of industries--primary metal [Standard Industrial Classification 33 (SIC 33)]; stone, clay, glass, and concrete (SIC 32); chemicals and allied products (SIC 28); transportation equipment (SIC 37); and fabricated metal products, except machinery (SIC 34)--constitute the major gas-consuming industries in the tri-state region. These industries utilized approximately 85% of all gas consumed by major end-users in the 10-county area (Table 3-14).

3.134
Primary metal production is the most important gas-consuming industry in the study area. The industry consumed more than 56.4 BCF of gas between April 1, 1977, and March 31, 1978,* or over 50% of all the natural gas consumed by large end-users. Iron and steel producers are the most important gas-consuming industries in five of the ten counties in the study area (Chautauqua and Erie counties, New York; Erie County, Pennsylvania; Cuyahoga and Lorain counties, Ohio) and are second in importance in two other counties. A listing of the ten largest gas-consuming companies in the region includes nine primary metal producers. The largest, Jones & Laughlin (Cuyahoga County, Ohio), consumed 13.1 BCF of gas between April 1977 and March 1978 (Table 3-15).

3.135
Stone, clay, glass, and concrete producers constitute the second most important group of gas-consuming industries in the region, utilizing about 9.5 BCF of gas. Geographically, this industry is highly concentrated in Ohio, particularly in the western part of the study area. It is the major gas-consuming industry in Erie, Sandusky, and Ottawa counties.

3.136
Chemicals and allied products comprise the third largest group of gas-consuming industries, utilizing approximately 7.7 BCF of gas. Although the industry is located in several counties of the study area, it is highly concentrated in northeastern Ohio (Ashtabula and Lake counties) where it is the most important gas-consuming industry. The chemicals and allied products industry experienced some of the largest gas curtailments (both in volume and as a percentage of total requirements) during the 12-month period ending on March 31, 1978.

Planned Projects

3.137
Proposed projects that are anticipated to be implemented around the Lake in New York, Pennsylvania, and Ohio are listed in Table 3-16. Certain projects are being implemented at this time and will continue into the future in all the counties.

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*These projections (McGraw-Hill 1978), based on the most current information available at the time of the Phase I report preparation (McGregor et al. 1978), have been treated as actual data in the text for the purpose of readability and have not yet been updated to "reported data" status.

Table 3-14. Projected Total Natural Gas Deliveries and Curtailments to Major Industrial Groups for the Reference Program Study Region, April 1977-March 1978[a]

SIC[c]	Major Industrial Group	Natural Gas (MCF)[b] Deliveries	Curtailments
33	Primary metal	56,429,065	1,484,193
32	Stone, clay, glass, concrete	9,585,232	583,003
28	Chemicals, allied products	7,731,597	1,013,144
37	Transportation equipment	6,853,219	166,778
34	Fabricated metal products, except machinery	4,664,996	468,251
36	Electrical, electronic machinery	2,451,157	462,537
20	Food and kindred products	2,430,796	933,799
35	Machinery, except electrical	2,159,126	103,672
30	Rubber, miscellaneous plastics products	2,138,680	344,605
29	Petroleum refining, related industries	1,252,851	410,828
39	Miscellaneous manufacturing industries	1,015,753	106,583
26	Paper, allied products	955,594	20,808
80	Hospitals	485,368	0
82	Schools	413,678	11,842
40	Railroad transportation	347,262	6,730
49	Electric utilities	323,639	56,107
22	Textile mill products	254,906	119,423
25	Furniture, fixtures	198,241	3,547
27	Printing, publishing	170,038	0
52	Building materials, hardware stores	110,236	0
96	Economic programs	109,248	68,256
1	Agricultural, crops	100,567	24,725
65	Real estate	98,698	1,593
70	Hotels, lodging places	94,533	0
50	Wholesale trade--durables	84,276	47,385
	Total	100,498,756	6,437,809

[a]Data from McGraw-Hill, Inc. (1978) (see Footnote a to Table 3-13).

[b]MCF = thousands of cubic feet. To convert cubic feet to cubic meters, multiply by 0.02832.

[c]SIC = Standard Industrial Classification.

Table 3-15. Projected Largest End-Users of Natural Gas in the Reference Program Study Region, April 1977-March 1978[a]

Company	Deliveries (MCF)[b]	SIC[c]	County
Jones & Laughlin Steel Corp.	13,118,316	33	Cuyahoga, Ohio
Bethlehem Steel Corp.	7,874,000	33	Erie, New York
Republic Steel Corp.	6,390,000	33	Cuyahoga, Ohio
U.S. Steel Corp.	6,317,452	33	Lorain, Ohio
U.S. Steel Corp	2,115,977	33	Cuyahoga, Ohio
National Forge	2,100,000	33	Erie. Pa.
Aluminum Company of America	2,051,006	33	Cuyahoga, Ohio
Ford Motor Co.	1,880,147	33	Cuyahoga, Ohio
Chevrolet River Road Plant	8,829,449	37	Erie, New York
Republic Steel Corp.	1,752,593	33	Erie, New York
Huron Lime	1,120,202	32	Erie, Ohio
Union Carbide Corp.	1,063,477	32	Ashtabula, Ohio

[a] Data from McGraw-Hill, Inc. (1978) (see Footnote a to Table 3-13). A large end-user is defined as using > 1 billion cubic feet (BCF) of gas during a 12-month period. One BCF = 28.32 million cubic meters.

[b] MCF = thousands of cubic feet. To convert cubic feet to cubic meters, multiply by 0.02832.

[c] SIC = Standard Industrial Classification.

Table 3-16. Proposed Projects by State and Region

State/Region	Project	Time Frame
New York		
Chautauqua	Construction of one 850-MW coal-fired electric generating unit[a,h]	Completion date: 1989
	Development of small harbors and commercial and recreational fishing[b]	Future
Erie	Development of Buffalo Harbor[c]	Future
Pennsylvania		
Erie	Construction of fossil fuel power plant(s)[d]	Completion dates: 1980s-1990s
	Development of Erie Harbor[e]	Future
	Construction of iron and steel manufacturing complex[f]	Future
	Construction of a 225-300 kV, 900-1200 MW electric submarine cable from Ontario, Canada, to Lake City, Pa. (Erie County)[h]	1983-1985
Ohio		
Ashtabula	Construction of iron and steel manufacturing complex[f]	Future
Cuyahoga	Construction of regional jetport[g]	Future
	Development of Cleveland Harbor[g]	Future
Regional	Development of more recreational opportunities	Continuous
	Prevention of shoreline erosion	Continuous
	Enhancement of scenic/esthetic quality of shoreline	Continuous
	Prevention of agricultural runoff	Continuous
	Improvement of water quality	Continuous

[a]U.S. Army Engineer District, Buffalo-A (undated).

[b]Chautauqua County Planning Board (1978).

[c]Brundage (1978).

[d]Erie County Department of Planning and Erie County Metropolitan Planning Commission (1978).

[e]Erie Metropolitan Planning Department (1975).

[f]U.S. Army Engineer District, Buffalo-B (undated).

[g]Regional Planning Commission (1977).

[h]Marks (1980--personal communication).

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CHAPTER FOUR: CONSEQUENCES OF THE PROPOSED ACTION AND ALTERNATIVES

4.001
In this chapter, the consequences of both the Reference Program and the Onland Alternative Program are discussed with regard to the environment of the Lake Erie region. Other alternatives--including development of Outer Continental Shelf reserves in the Gulf of Mexico, development of Alaskan reserves, and regional reduction in demand due to conservation of natural gas--have been discussed in Chapter 2, since these alternatives either lack regional and technological specificity or have been fully analyzed in other impact assessments.

SHORELINE GEOLOGY AND EROSION

Impact Sources

4.002
Activities of the Reference Program which potentially could impact the nearshore and farshore areas are summarized in Table 4-1. It is assumed that gas is brought ashore at 10 pipeline landfalls. Each landfall would be located within a 10-mile band (Figure 1-1, map pocket) depending on the location of lease area fields and shoreline constraints. Each landfall must be sited using state-of-the-art analytical procedures. If the Reference Program is approved in principle, the Corps and USEPA may require operators filing for federal permits to provide site-specific pipeline engineering designs and appropriate environmental information to assess whether or not each landfall proposal complies with program guidelines and avoids sensitive areas as described in Table 1-7. Activities of the Onland Alternative Program are excluded from the shoreline area (0.5 mile from the lakeshore).

Impacts of the Reference Program

4.003
The major source of impact to shorelines would be from landfall and pipeline corridor construction and maintenance in both the development and decommissioning phases. These activities would modify topography and increase local

Table 4-1. Summary of Possible Sources of Impacts to Shorelands from Reference Program Activities

Program Phase	Activity
I. Exploration and development	Pipeline construction through the shoreline from the Lake to production facilities
II. Production	Routine maintenance of pipeline right-of-way
	Pipeline rupture
III. Decommissioning	Removal of pipelines along the shore

shoreline erosion rates. Locally, the construction disturbance can result in increased potential for sloughing and landslide hazards in adjacent areas. The degree of impact would depend on construction methods, timing of construction, erosion control methods, and the physical characteristics and features of each landfall site. Actual intrusion in shoreline areas and construction-decommissioning impact would be short-lived and temporary. However, postconstruction and postdecommissioning stabilization can affect the local and adjacent shoreline erosion rates over long periods of time. But, considering the overall trend in shoreline erosion management and the decreased erosion rates that might be expected from successful stabilization at the projected 10 landfall sites, impacts would be minimal. Secondly, less than 1 mile (total) or less than 0.1% of the 240 miles of shoreline in the Reference Program Study Region would be affected. Thus, the overall impact on the shoreline and coastal zone is expected to be negligible.

GROUNDWATER HYDROLOGY

Impact Sources

4.004
Activities of the Reference Program and Onland Alternative Program that are possible sources of environmental impact are summarized in Table 4-2.

Impacts of the Reference Program

4.005
The major sources of impact on groundwater are drilling and onland pipeline construction. Other sources of potential impact will include the landfilling of Reference Program solid wastes and deep well injection of some liquid wastes (formation waters). There is potential for degradation of water quality and disruption of aquifer transmissive properties from drilling, improperly plugged dry holes, and casing ruptures. These effects, however, would be localized and limited to areas within the Lake. As noted in Chapter Three, groundwater in deep water-bearing formations of early Devonian age or older contain saline and/or highly mineralized water of poor quality. Thus any additional, even widespread, contamination would have only a minor impact on the groundwater resources beneath the Lake. Since there are no users of this groundwater, there will be no water-use impacts.

4.006
Pipeline corridor clearing and construction has the potential to affect infiltration (recharge rates) and thus degrade shallow groundwater quality. Infiltration (recharge) is the sole source of (1) soil moisture to sustain the growth of vegetation and (2) the groundwater supply of wells, springs, and streams. The soil surface divides rainfall into overland flow (runoff) and soil moisture and groundwater (saturated zone). Some of the most important factors influencing infiltration rates are soil physical characteristics (e.g., particle size, degree of particle aggregation, and arrangement of particles and aggregates) and features of the soil surface (slope, vegetative cover, and drainage).

4.007
Spills, agricultural practices (fertilizer), and waste management facilities (landfill and septic system leachates) can release contaminant fluids into the

Table 4-2. Summary of Possible Sources of Impact to Groundwater Hydrology from Activities Related to Natural Gas Development

Program Phase	Activity: Reference Program	Activity: Onland Alternative Program
I. Exploration and development	Drilling fluids contaminate aquifers	Drilling fluids contaminate aquifers
	Open wellbores, improper casing	Open wellbores, improper casing
		Clearing and trenching in groundwater recharge areas
		Infiltration of fluids from mud pits
	Onshore disposal of solid wastes (landfill)	
	Onshore disposal of liquid wastes (Injection wells)	
II. Production	Casing ruptures	Casing ruptures
III. Decommissioning	Casing or plug fails	Casing or plug fails

environment. Construction activities (including pipeline corridor clearing and trenching) that disturb the existing soil cover and physical properties can alter the infiltration rate and pathway of contaminant fluids into and through the soil. Any activity that provides a more direct access for contaminants to subsurface aquifers will increase the potential to degrade groundwater quality beyond what existed previously. This is worthy of discussion because many public and private domestic water users in nearshore areas (lake plain) derive their water supplies from shallow unconsolidated or near-surface bedrock aquifers of fair to good quality. These aquifers have been noted (in some areas of Ohio) to be polluted through improperly designed sanitary systems and landfill construction activities (Great Lakes Basin Comm. 1975a). However, the additional incremental impact on groundwater resources in backshore and inland areas from 10 widely spaced landfall and pipeline corridors properly sited and constructed will be negligible.

4.008
Landfilling of domestic waste, drill cuttings, and certain sludges derived from fluids treated in onland settling ponds will be necessary for wastes generated on the Lake from the Reference Program. The volumes of waste are not great and they will be generated over a period of 34 years. However, there is a lack of landfill facilities near ports on the southern shore of Lake Erie. New landfills could be developed for this purpose, landward from the Lake to coal mining areas (up to 150 miles). In any case, existing landfills would be utilized--where practical, available, and appropriately designed--to accommodate specific wastes. Some existing landfill sites are presently

polluting groundwater (Great Lakes Basin Comm. 1975a) and must be avoided. There would be low potential for additional groundwater degradation if the wastes are disposed of in existing or new settling ponds and/or landfills that are properly designed and constructed and that meet applicable criteria and regulations.

4.009
In the Reference Program, it is assumed that formation waters (naturally occurring saline solutions) will be disposed of by well injection into deep isolated geologic formations. New injection wells would probably be drilled as close as possible to onland gas production facilities (where the saline formation water is separated from the gas) to avoid added costs of liquid waste transport to other sites. If these wells are properly developed in appropriate host formations sufficiently isolated (hydraulically disconnected) from shallow freshwater aquifers, the risks of contamination would be low. The total amount of fluid to be injected is estimated to range between 3.7 million to 4.6 million bbl (Table 1-32) over the lifetime of the program. The deepest apparently suitable host formation (Cambrian Mt. Simon Formation) in the region averages about 2000 ft below the deepest freshwater aquifer (Devonian-Silurian carbonates) and is separated from it by a number of low-permeability formations. Thus, considering that (1) deep formation waters are already saline and highly mineralized, (2) the volume of fluid to be injected through 10 widely spaced locations is relatively small and (3) the intervening low-permeability formations are relatively thick, the impacts related to deep well injection are expected to be minor.

Impacts of the Onland Alternative Program

4.010
More sources of impact would be generated by the Onland Alternative Program than by the Reference Program. A land-based program would not only provide more areas of impact potential but would also result in higher potential for and greater magnitude of impacts.

4.011
Generally, the Onland Alternative Program can impact both shallow and deep groundwater aquifers in the same manner as discussed for the Reference Program. The major distinction between the programs is the magnitude of the potential for impacts on water quality and/or water users. There are fewer freshwater aquifers beneath the Lake than landward of the Lake, and these aquifers are generally of low quality and are not known to be utilized. Thus, the potential for impacts is extremely low (negligible). However, in the Onland Alternative Program, more freshwater aquifers of higher quality would be encountered. Hence, the potential for adverse impact must be considered several orders of magnitude greater for the Onland Alternative Program. This impact would be particularly acute in portions of lake-bordering counties where high pollution potential exists. Here, additional degradation of existing, low-quality groundwater would severely restrict its use. Further inland, there are more freshwater aquifers available and there is a proportionately greater dependence on them for water supply than in the lake-bordering areas where abundant lake water is available. Thus, there is more potential for adverse impacts to groundwater aquifers, thereby limiting their unrestricted use and possibly resulting in hardship to users.

4.012
Pipeline corridor clearing, trenching, construction, and maintenance also have potential to degrade shallow groundwater quality and affect aquifer recharge rates in the Onland Alternative Program. Again, the comparison is drawn to the Reference Program in which only 10 new pipeline corridors (on the order of 10 miles) are planned as opposed to complete networks (thousands of miles) of gathering systems and trunk lines expected for the Onland Alternative Program. Thus, the potential for adverse impacts is expected to be at least an order of magnitude greater. It should also be noted that with greater dependence on shallow aquifers for water supply away from the Lake (the lower tier of counties), the severity of these impacts would likewise be greater.

4.013
Mud pits usually associated with land-based drilling rigs can also provide a source of impact to groundwater resources. Contaminants in leachate seeping from mud pits can degrade groundwater quality. As noted above, similar pollution problems related to landfills have occurred in northeastern Ohio and northwestern Pennsylvania. There are no mud pits proposed in the Reference Program, whereas there would be one for nearly all of the estimated maximum of 500 wells per year drilled in the Onland Alternative Program. It is anticipated that the majority of onland wells would be located inland from the Lake where groundwater resources are more abundant, higher in quality, and important sources of water supply. Thus, there is high potential for severe adverse impact on local groundwater resources, which is especially significant in terms of long-term seepage impacts in the states of Pennsylvania and New York where mud pits can simply be covered over. In Ohio, the contents of the mud pits would be disposed of in approved landfills and the site of the mud pit reclaimed to specific conditions.

4.014
One other source of impact related to land-based drilling is land clearing for the drill site and access road (approximately 3 acres per site). This activity can also act to impact local groundwater hydrology and recharge rates in a manner similar to pipeline clearing. Considering the annual area committed to onland drill sites (1500 acres), the normally local and minor disturbances could affect a large number of groundwater users in landward portions of the Onland Alternative Program Study Region.

4.015
The problems associated with waste disposal for the Onland Alternative Program are considered minor in comparison to the other impact sources. Generally, solid waste disposal is less of a problem than for the Reference Program, because wastes can be disposed of in more diverse locations.

4.016
Therefore, the Onland Alternative Program is considered to have orders of magnitude greater impact on the region's groundwater resources and water use and is less acceptable than the Reference Program.

WATER QUALITY

Impact Sources

4.017
The 1978 Water Quality Agreement between the United States and Canada calls for a maximum effort to (1) develop programs, practices, and technologies for a better understanding of the Great Lakes Basin ecosystem and (2) eliminate or reduce to the maximum extent practicable the discharge of pollutants to the Great Lakes System. The actual implementation of the agreement objectives is through the appropriate federal, state, and provincial governments by enactment of legislation and establishment of water quality criteria, effluent limitations, guidelines, etc., with assistance and direction from the International Joint Commission. The Reference Program is consistent with the general objectives in that it limits discharges to the maximum extent practicable and incorporates technology to protect water quality.

4.018
Some activities of the Reference Program and the Onland Alternative Program could release materials to surface waters. The use of closed-cycle drilling prevents release of materials during surface hole drilling by the jack-up rig, secondary hole drilling, and production hole drilling. Materials produced by these activities would be disposed of onland, as would sanitary wastes from the lake drilling rigs. In addition to routine releases of materials to surface waters during some phases of the Reference Program and Onland Alternative Program, accidents may also result in releases. Potential impact sources of Reference Program accidents are listed in Table 1-35. Routine releases are discussed in Chapter One - Routine Activities, Fate of Materials Used and Residuals Generated.

Impacts of the Reference Program

4.019
The materials released to the Lake during construction activities, routine activities, and accidents; the parameters used to assess the impact of these releases; and the estimated potential impacts are listed in Tables 4-3, 4-4, and 4-5. The impacts on water quality of the releases are determined using (1) estimates of concentrations at the point of release and 0.5 mile downcurrent of the point of release, (2) relative frequency of the activity producing releases, (3) duration of the release, (4) drinking water standards, (5) effluent guidelines and limitations, and (6) water quality criteria for the protection of freshwater aquatic life. This analysis is based upon routine releases described in Chapter One and accidental releases described in Appendix C. The approach taken here is to determine the magnitude of impacts on water quality in the vicinity of the releases. Concentration estimates were made for selected materials that could impact water quality (resuspended sediment and other suspended particulates, hydrocarbons, heavy metals, and dissolved gases). Order-of-magnitude concentration estimates were made assuming worst-case conditions because of expected variability of quantities released and variability of environmental conditions under which releases could occur. Concentrations at the point of release were calculated for instantaneous releases by estimating the amount of discharged material that would dissolve or become suspended in the water column and the size of the initial dispersing water volume near the point of release. For continuous

Table 4-3. Potential Impact on Water Quality from Releases During Construction Activities

Activity: Release	Potential Impact	Assessment Parameters: Concentration (mg/L)[a] At Release Point	At 0.5 mile	Drinking Water Standards	Effluent Guidelines and Limitations	Freshwater Aquatic Life Criteria	Frequency	Duration
EXPLORATION AND DEVELOPMENT								
Construction or Modification of Harbor Facilities:								
Sediment (TSS)	Minor	-	-	1 NTU[b]	-	Footnote c	-	-
PRODUCTION								
Pipeline Construction (Construction or modification of harbor facilities):								
Sediment (TSS)	Minor	-	-	1 NTU[b]	-	Footnote c	-	-
Pipeline Laying and Burial:								
Sediment (TSS)	Minor	2×10^5	10	1 NTU[b]	-	Footnote c	-	-
Sanitary and Domestic Wastes:								
No release	No impact				No discharge of floating solids; delivery to approved onshore pumpout facility[d]			
DECOMMISSIONING								
None								

[a]Concentrations calculated only for constituents considered hazardous. Calculations for specific constituents that vary from site to site (e.g., specific chemical composition of sediments and cuttings) is not possible for the Reference Program.

[b]Data from USEPA (1976a).

[c]Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life (USEPA 1976b).

[d]Federal coastal subcategory point source requirements (based on proposed regulations) (USEPA 1979).

Abbreviations: TSS = total suspended solids; NTU = nephelometric turbidity unit.

A hyphen indicates data not available.

Table 4-4. Potential Impact on Water Quality from Releases During Routine Activities

Activity: Release	Potential Impact	Assessment Parameters: Concentration (mg/L)[a] At Release Point	Concentration (mg/L)[a] At 0.5 mile	Drinking Water Standards	Effluent Guidelines and Limitations	Freshwater Aquatic Life Criteria	Frequency (days/year)	Duration (days/or hours)
EXPLORATION AND DEVELOPMENT								
Move In, Rig Up—Jack-up Rig:	Minor							
Jack up - Sediment (TSS)		4×10^{3}	5×10^{-3}	1 NTU[b]	-	Footnote c	186 d/yr	< 1 h
Set caisson - Sediment (TSS)		6×10^{5}	2×10^{-2}	1 NTU[b]	-	Footnote c	186 d/yr	< 1 d
Drive 16-in. pipe - Sediment (TSS)		3×10^{5}	2×10^{-3}	1 NTU[b]	-	Footnote c	186 d/yr	< 1 d
Move In, Rig Up—Drillship:	Minor							
Set anchor - Sediment (TSS)		4×10^{3}	5×10^{-3}	1 NTU[b]	-	Footnote c	113 d/yr	< 1 h
Drill Surface Hole—Jack-up Rig:								
No release	No impact							
Drill Surface Hole—Drillship:	Minor							
Cuttings (TSS)		1×10^{4}	2	1 NTU[b]	Cuttings shall contain no free oil when discharged[d]	Footnote c	113 d/yr	1 d
Bentonite gel (TSS)		2×10^{2}	7×10^{-5}	1 NTU[b]	-	Footnote c	113 d/yr	1 d
Cement (TSS)		6	2×10^{-4}	1 NTU[b]	-	Footnote c	113 d/yr	1 d
Drill Secondary Hole—Drillship:								
No release	No impact				Cuttings shall contain no free oil when discharged[d]			
Drill Production Hole:								
No release	No impact				No discharge of drilling muds[d,e]			
Well Completion:								
No release	No impact				No discharge of produced waters[d]			
Rig Down, Move Off—Jack-up Rig:								
Sediment (TSS)	Minor	4×10^{3}	0.2	1 NTU[b]	-	Footnote c	-	-

Table 4-4. Continued

Activity: Release	Potential Impact	Concentration (mg/L)[a] At Release Point	At 0.5 mile	Drinking Water Standards	Effluent Guidelines and Limitations	Freshwater Aquatic Life Criteria	Frequency (days/year)	Duration (days/or hours)
		Assessment Parameters						
EXPLORATION AND DEVELOPMENT (Continued)								
Rig Down, Move Off—Drillship:								
Sediment (TSS)	Minor	4×10^4	5×10^{-3}	1 NTU[b]	-	Footnote c	-	-
Well Stimulation:	Minor				No discharge of stimulation fluids[d]; based on Canadian experience in Lake Erie, stimulation fluids are collected for onland treatment and disposal until the well flow rate decreases to 10 gal/min; then the well is flowed to the lake surface for 12 hours		207 d/yr	1 d
Sand (TSS)		-	-	1 NTU[b]	-	Footnote c	-	-
Bentonite gel (TSS)		-	-	1 NTU[b]	-	Footnote c	-	-
Hydrochloric acid		-	-	pH 6.5–8.5[f]	-	pH 6.5–9.0[g]	-	-
Surfactants		-	-	0.5 mg/L[f]	-	-	-	-
DECOMMISSIONING								
Well Decommissioning:	Minor							
Produced waters		-	-	-	No discharge of produced waters[d]	-	-	-
ALL ACTIVITIES								
Sanitary and Domestic Wastes								
No release	No impact				No discharge of floating solids; delivery to approved onshore pumpout facility[d]			

[a]Concentrations calculated only for constituents considered hazardous. Calculations for specific constituents that vary from site to site (e.g., specific chemical composition of sediments and cuttings) is not possible for the Reference Program.

[b]Data from USEPA (1976a).

[c]Settleable and suspended solids should not reduce the depth of compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life (USEPA 1976b).

[d]Federal coastal subcategory point source requirements (based on proposed regulations) (USEPA 1979).

[e]Assumes that certain drilling muds and fluids contain toxic constituents.

[f]Data from USEPA (1977b); surfactants included in standards for foaming agents.

[g]Data from USEPA (1976b).

Abbreviations: TSS = total suspended solids; NTU = nephelometric turbidity unit.

A hyphen indicates data not available.

Table 4-5. Potential Impact on Water Quality from Releases due to Potential Accidents

Activity: Release	Potential Impact	Concentration (mg/L)[a] At Release Point	Concentration (mg/L)[a] At 0.5 mile	Drinking Water Standards	Effluent Guidelines and Limitations	Freshwater Aquatic Life Criteria	Frequency[b]	Duration (days)
				Assessment Parameters				
EXPLORATION AND DEVELOPMENT								
Loss of Well Control (from basement test well drilling):	Moderate and localized						Very low	15 d
Oil (liquid hydrocarbons)			-	-	Well must be plugged[c]	3×10^{-3} mg/L[d]		
Jack-up Rig or Drillship Capsize:	Moderate and localized						Very low	Temporary
Calcium chloride		3×10^{4}	0.6	250 mg/L (as Cl^-)[e]	-	-	-	-
Bentonite (TSS)		-	-	1 NTU[f]	-	Footnote g	-	-
Cement		-	-	1 NTU[f]	-	Footnote g	-	-
Starch polymer		-	-	-	-	5 mg/L (DO)[d]	-	-
Drilling mud		-	-	1 NTU[f]	No discharge of drilling muds[c,h]	Footnote g	-	-
Chrome lignosulfonate		100	3×10^{-3}	0.05 mg/L (as Cr)[f]	No discharge of drilling muds[c,h]	0.1 mg/L (as Cr)[d]	-	-
Magconol		-	-	-	No discharge of drilling muds[c,h]	-	-	-
Polybrine		-	-	500 mg/L (TDS)[f]	No discharge of drilling muds[c,h]	-	-	-
Mixical ($CaCO_3$)		-	-	-	No discharge of drilling muds[c,h]	-	-	-
Ceastop (polymer and $CaCO_3$)		-	-	-	No discharge of drilling muds[c,h]	-	-	-
Barite ($BaSO_4$)		1000	3×10^{-2}	1 mg/L (as Ba)[f] 250 mg/L (as SO_4)[e]	No discharge of drilling muds[c,h]	-	-	-
Abietylamine (filming amine)		-	-	-	No discharge if contained in waters produced from well completion[c]	-	-	-
Sodium sulfite		-	-	-	-	5 mg/L (DO)[d]	-	-
Diesel fuel		-	-	-	-	1.6 mg/L[d]	-	-
Sodium hydroxide		-	-	pH 6.5-8.5[e]	-	pH 6.5-9.0[d]	-	-
Sanitary and domestic wastes		250 (BOD_5)[i] 250 (TSS)[i]	- -	1 FC/100 mL 1 NTU[f]	No discharge of floating solids; delivery to approved onshore pumpout facility[c]	5 mg/L (DO)[d]	-	-

Table 4-5. Continued

Activity: Release	Potential Impact	Concentration (mg/L)[a] At Release Point	Concentration (mg/L)[a] At 0.5 mile	Assessment Parameters: Drinking Water Standards	Effluent Guidelines and Limitations	Freshwater Aquatic Life Criteria	Frequency[b]	Duration (days)
EXPLORATION AND DEVELOPMENT (Continued)								
Stimulation Barge Capsize:	Moderate and localized						Very low	Temporary
Hydrochloric acid		-	-	pH 6.5–8.5[e]	-	pH 6.5–9.0[d]	-	-
Surfactant		1×10^3	4×10^{-4}	0.5 mg/L[e]	-	-	-	-
Calcium chloride		2×10^3	5×10^{-2}	250 mg/L (as Cl^-)[e]	-	-	-	-
Bentonite (TSS)		-	-	1 NTU[f]	-	Footnote g	-	-
Nitrogen gas		-	-	-	-	≤100% saturation	-	-
Carbon dioxide		-	-	-	-	≤100% saturation	-	-
Loss of Well Control (from development well drilling or from ruptured wellhead):	Moderate and localized						Very low	15 d
Raw natural gas		-	-	-	Well must be plugged[c]	<50 mg/L[j]	-	-
Condensate (liquid hydrocarbons)		10	5×10^{-3}	-	Well must be plugged[c]	-	-	-
Formation water		-	-	-	No discharge of produced waters[c]	-	-	-
Hydrogen sulfide		10	6×10^{-3}	0.05 mg/L[e]	-	2×10^{-3} mg/L[d]	-	-
All Activities:								
Deck drainage	No impact				No discharge of free oil[c]			
PRODUCTION								
Gas Pipeline Break:	Moderate and localized						Very low	3 d
Raw natural gas		-	-	-	-	<50 mg/L[j]	-	-
Condensate (liquid hydrocarbons)		30	1×10^{-2}	-	-	-	-	-
Hydrogen sulfide		300	0.1	0.05 mg/L[e]	-	2×10^{-3} mg/L[d]	-	-

Table 4-5. Continued

Activity: Release	Potential Impact	Assessment Parameters: Concentration (mg/L)[a] At Release Point	At 0.5 mile	Drinking Water Standards	Effluent Guidelines and Limitations	Freshwater Aquatic Life Criteria	Frequency[b]	Duration (days)
PRODUCTION (Continued)								
Glycol Line Break:	Minor and localized						Very low	1 d
Polyethylene glycol		20	1.0	-	-	140 μg/L[j]		
DECOMMISSIONING								
None								

[a]Concentrations calculated only for constituents considered hazardous. Calculations for specific constituents that vary from site to site (e.g., specific chemical composition of sediments and cuttings) is not possible for the Reference Program.

[b]Relative frequency based on comparisons of different types of accident occurrences (absolute frequencies could not be calculated).

[c]Federal coastal subcategory point source requirements (based on proposed regulations) (USEPA 1979).

[d]Data from USEPA (1976b).

[e]Data from USEPA (1977b).

[f]Data from USEPA (1976a).

[g]Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonably established norm for aquatic life (USEPA 1976b).

[h]Assumes that certain drilling muds and fluids contain toxic constituents.

[i]Data from Clark et al. (1971).

[j]Data from Cleland and Kingsbury (1977).

Abbreviations: TDS = total dissolved solids; TSS = total suspended solids; NTU = nephelometric turbidity unit; DO = dissolved oxygen; BOD_5 = 5-day biochemical oxygen demand; FC = fecal coliform.

A hyphen indicates data not available.

releases, estimates of concentrations included consideration of the release rate, current speed, and assumed configuration of the water volume into which the material is mixed near the point of release.

4.020
Concentrations of contaminants at a distance of 0.5 mile were estimated using turbulent dispersion theory. For instantaneous releases, the results represent estimated concentrations at the center of a dye patch resulting from a point source, after a diffusion time corresponding to the time required for transport over a distance of 0.5 mile at the ambient current speed. These concentration estimates were arrived at by assuming that the dye patch maintains a binormal concentration distribution (Murthy 1976) and by using values for the variance of the concentration distribution along, and perpendicular to, the current direction derived from Murthy's data for Lake Ontario. For continuous releases, the concentration estimates at 0.5 mile are plume centerline concentrations at that distance, determined with the model described by Brooks (1960). In making these estimates, current speeds in the bottom 6 ft of the water column were assumed to be 2 cm/s. At higher levels in the water column, current speeds were assumed to be 55 cm/s, consistent with maximum current speeds observed in Lake Erie (Hamblin 1971) and with the use of parameter values that would tend to give worst-case concentration estimates. All materials, including particulates, were assumed to behave conservatively once dissolved or suspended in the water column. Since particulates settle out of the water column at a rate depending on their density and size, this assumption would also tend to result in overestimates of concentrations.

4.021
Sediment resuspension is unavoidable during certain phases of the Reference Program (Tables 4-3 and 4-4). Sediment releases from program activities will be temporary; the release sites will be dispersed throughout the U.S. waters of Lake Erie. Natural processes in aquatic ecosystems can concentrate the following in bottom sediments: heavy metals, chlorinated hydrocarbons, pesticides, nutrients, and petroleum-related hydrocarbons (Burks and Engler 1978). During sediment resuspension, most of these compounds will be retained or resorbed by particulates and redeposited on the lake bottom. Compounds left in the water column will be dispersed rapidly. Impacts to water quality should be minor due to the localized and temporary nature of sediment resuspension. Natural shoreline erosion and turbulent resuspension are the dominant sources of suspended sediments in Lake Erie (Sly 1976).

4.022
During well stimulation and decommissioning, routine releases of fluids are unavoidable (Table 4-4). Fluid releases from program activities will be temporary and at sites dispersed throughout the Reference Program Study Region. Fluids will be released into the water column in small quantities and dispersed rapidly during decommissioning and stimulation. Impacts to water quality should be minor due to the localized and temporary nature of fluid releases.

4.023
Releases of petroleum-related hydrocarbons, raw natural gas, and polyethylene glycol will occur only during accidents (Table 4-5). The postulated accidents that produce these releases are loss of well control, rig or barge capsize, gas-line breakage, and glycol-line breakage. Occurrence of these accidents is highly unlikely (Table 1-35). Although loss of well control would result in

releases of petroleum-related hydrocarbons for periods of up to 15 days, the releases would be small and would impact localized areas. Hydrocarbon concentrations from releases should be dispersed to background concentrations fairly rapidly. A rig capsize, releasing diesel fuel, would also impact localized areas. Polyethylene glycol, released during a glycol-line break, would not substantially impact water quality directly, although chlorination of these compounds in a potable water intake is a potential source of impact (see section on Municipal/Industrial Water Supplies). The carcinogenicity (ability to produce or initiate cancer) and/or toxicity of the reaction between polyethylene glycol and aqueous chlorine is presently unknown.

4.024
If jack-up rigs, drillships, or stimulation barges capsize, numerous compounds would be released into Lake Erie (Table 4-5). Potentially toxic compounds, such as chrome lignosulfonate, barite, and hydrogen sulfide would be rapidly dispersed or removed from the water column by escaping into the atmosphere or by adsorption onto particulates and deposition on the lake bottom. Impacts to water quality would be minimal due to the localized and temporary nature of discharges from capsized vessels.

4.025
The Reference Program has been designed to comply with existing effluent guidelines and regulations. Little degradation of Lake Erie water quality is expected to result from Reference Program activities because releases are small relative to the volume and surface area of Lake Erie, their effect is localized and temporary, and rapid dispersion to very low levels is expected (Tables 4-3, 4-4, and 4-5).

Impacts of the Onland Alternative Program

4.026
Materials released into the environment from the Onland Alternative Program during routine operations or accidents are similar to those released during the Reference Program (Tables 4-3, 4-4, and 4-5). Impacts to surface water quality will be site-specific and dependent upon existing meteorological conditions. Unless program operations are sited in or near surface waters, released materials should enter surface waters only during precipitation events.

4.027
Materials (hydrocarbons, drilling fluids, brine, stimulation fluids, etc.) released during program operations should enter surface waters in small quantities or low concentrations during periods of high precipitation and should be dispersed rapidly. Thus, impacts to surface water quality should be minor. Loadings of suspended solids to surface waters could be increased during most phases of the Onland Alternative Program. However, state-of-the-art erosion control techniques--e.g., straw bales used as filters, sediment holding ponds, and diversion ditches--can minimize increases in solids loadings to area streams. Solids loadings from this program, however, should be small compared to other anthropogenic and natural loadings. Overall, impacts to surface water quality should be minor due to the localized and temporary nature of the suspended solids loadings.

AQUATIC ECOLOGY

Impact Sources

4.028
Impacts to the aquatic biota of Lake Erie from Reference Program activities may occur either directly to an organism from the chemical and/or physical action of a discharge or indirectly from an activity that affects an organism by modifying its habitat or environment. Table 4-6 lists those sources of impact which have the greatest potential for affecting Lake Erie biota. Other sources of impact occur from the Reference Program, but are expected to be indistinguishable from natural variations in environmental conditions based on the following criteria: (1) discharges are chemically inert and/or nontoxic, small in quantity, rapidly dispersed, and do not violate legal discharge criteria; and (2) habitat modification affects a small area, is of short duration, is insignificant compared to analogous natural activities, and/or is located in biologically uninhabitated or depauperate areas.

Table 4-6. Summary of Possible Sources of Impacts to Aquatic Biota from Activities Related to Natural Gas Development

	Activity	
Program Phase	Reference Program	Onland Alternative Program
I. Exploration and Development	Jack-up rig leg withdrawal	Site preparation and clearing
		Service water withdrawal for drilling
	Well stimulation releases	Release of waste fluids and waste disposal during drilling and stimulation
	Pipeline construction in the nearshore zone	Pipeline construction across streams
II. Production		Waste disposal
		Accidental spills
III. Decommissioning	Release of fluids	Release of fluids

4.029
Examples of minor sources of impact are resuspension of small amounts of sediment during rig jack-up or drillship setup, most routine drilling operation discharges, cementing, deck drainage, and offshore pipeline construction. In many cases, the designed location of a development activity greatly reduces the magnitude of impacts. For example, most Lake Erie fishes spawn in shallow inshore waters or tributaries (see Table 3-2). Since drilling will be prohibited in these areas, the potential impacts to early life stages of fish (eggs and larvae) are greatly reduced.

4.030
Sources of impact from the Onland Alternative Program are identified in Table 4-6.

Impact Assessment--Plankton, Benthic Macroinvertebrates, and Macrophyton

Impacts of the Reference Program

4.031
The release of sediments and any associated contaminants during rig leg withdrawal presents a potential source of impact if components of the plankton come in contact with the suspended material. Although Konasewich et al. (1978), Kemp et al. (1976), and Walters et al. (1974) indicated accumulation of metals and organic contaminants in varying concentrations in the lake sediments, Ferrante et al. (1980) reported no mobilization of mercury and zinc in resuspension studies on a jack-up rig in Lake Erie. The study was done under aerobic conditions, and little resuspension was observed. If resuspension occurs in thick, organic sediments during anoxic conditions, the release of contaminants may be of a greater magnitude. Even though contaminants are released, the plankton community may be spatially isolated from the material since phytoplankton and zooplankton are usually associated with surface waters, whereas resuspension would occur near the lake bottom. In areas where there is heightened concern over the potential for resuspension of contaminated sediment from jack-up rig removal, i.e., areas peripheral to dredge disposal sites, the use of sediment curtains that surround the rig could be investigated. Unfortunately, since all proposed development areas are at least one mile from shore and consequently usually in deep (30 ft or greater) water, the use of sediment curtains might be ineffectual if not economically prohibitive. The curtain would have to extend from the lakebed to a safe distance below the lake's surface to allow service vessels access to the rig without the potential for propeller fouling; its deployment would require several service vessels and could not take place until after the rig was set up onsite (sediment suspended during rig placement could, therefore, not be contained). The size and, hence, cost of the curtain would also have to be great to allow an adequate margin of safety during rig jack-down and removal.

4.032
Sediments will also be resuspended during trenching and pipe-laying activities. Since underwater pipelines must traverse shallow nearshore waters, phytoplankton and zooplankton could come into contact with resuspended sediments from pipeline construction activities. During these events, a local impact may be detected in the plankton community.

4.033
The amount of lake bottom habitat disrupted by the placement of four jack-up pads per rig will be about 1600 ft^2. Additional area will be disrupted or destroyed during pipeline construction in the nearshore zone. If one assumes a trench 3 ft wide and an additional disturbed area extending 3 ft on either side (a total of 9 ft), approximately 1.1 acres of lake bottom would be affected for each mile of pipeline to shore. The proposed program includes 10 landfalls or a total area disrupted by pipeline construction in the nearshore buffer zone of 11 acres. This area represents < 0.01% of the total lake bottom within one mile of the shore in the central and eastern basins. In addition, the benthic macroinvertebrates lost during construction will be

rapidly replaced by natural reproduction and immigration from surrounding areas.

4.034
Benthic organisms are normally subjected to high concentrations of suspended solids in the naturally occurring floc layers often present at the sediment-water interface. Additional particulate material is resuspended during storm events when nearshore habitats may be subject to large-scale modification. It is, therefore, highly unlikely that more than a minimal, short-term impact would occur during pipeline construction. In addition, no impact would result from resuspension of contaminants since the benthic community is in intimate contact with the contaminants in the undisturbed habitat.

4.035
Fluid releases from well stimulation are approximately 65 gal of HCl, 3 gal of surfactants, and 2400 gal of water per well. Since most of the return is water and since acids injected into the well will be partially neutralized, only a local pH change is expected in the Lake. No impact to the plankton or benthos is anticipated from the acid release. The surfactants discharged to the Lake following stimulation are organic compounds, some of which are toxic to aquatic organisms (Borodczak 1968). The release of these compounds may cause a decrease in the number of plankton organisms in the vicinity of the activity. The areal impact of the discharge on plankton depends on the concentrations of material in the effluent and the rate of dispersion. No impacts to benthic macroinvertebrates are anticipated.

4.036
In the course of seasonal drilling and over the period of time required to develop a lease area, cumulative lakewide impacts to aquatic biota from the release of stimulation fluids are expected to be minimal (for discussion of Reference Program assumptions concerning stimulation procedures, see Chapter One - Description of the Reference Program, Routine Activities). This is due mainly to large mandatory spacing requirements (0.5 mile between wells in Lockport reef lease areas and 1.0 mile in Clinton-Medina lease areas), the diffuse nature of stimulation activities (a maximum of three stimulation barges will be working at any one time), the relatively small amounts of releases per well, and an exceptionally large-volume and well-flushed receiving water body.

4.037
The release of $\sim$ 1000 gal of completion fluids during well decommissioning would probably have an impact on plankton organisms similar to that of well stimulation. The magnitude of chronic or sublethal impacts and area affected will depend on the chemical nature of the release and its dispersion in the Lake.

4.038
Activities of the Reference Program, especially trenching for laying of pipelines, could disturb aquatic macrophyte communities. This disturbance, however, would not be extensive areally and would be temporary. Recolonization of the disturbed area should occur rapidly.

Impacts of the Onland Alternative Program

4.039
The loading of inert solids to stream ecosystems from the preparation of the drilling sites and pipeline construction (Table 4-6) may result in negative responses in the populations of macroinvertebrates below the source of sediment. These responses may be in the form of a decrease in population density (Gammon 1970; Chisholm and Downs 1978; Herbert et al. 1961), or a shift in species composition or diversity indices (Barton 1977; Chisholm and Downs 1978).

4.040
The magnitude of any impact from sedimentation of inert solids is a function of factors acting in opposition or in concert to produce an alteration in the population. Important factors that affect sedimentation in the Onland Alternative Study Region are listed in Table 4-7.

Table 4-7. Factors Affecting the Magnitude of Impact of Onland Alternative Program on Aquatic Biota

Process	Factor
Sedimentation	Land gradient
	Soil type
	Precipitation
	Proximity, size, and quality of receiving water body
	Overall land use
	Season
	Organism sensitivity
Chemical additions	Handling protocol
	Chemical type and quality
	Season
	Proximity, size, and quality of receiving water body
	Organism sensitivity
	Frequuncy, amount, and longevity of release
Habitat modification	Stream gradient
	Proximity, size, and quality of receiving water body
	Organism sensitivity
	Frequency and amount of withdrawal

4.041
Two interrelating factors that influence the susceptibility of macroinvertebrates to impact are species composition and overall land use. Land bordering Lake Erie is a mixture of cropland, pasture, and forest (see Figure 3-2).

Aquatic invertebrate species found in agricultural and pasture regions are usually more tolerant of inert solids since watercourses in these regions are already subject to higher sediment loading from enhanced erosion. Streams in the forested regions at higher elevations, although not normally subjected to heavy sediment loading, are, however, more susceptible to impact from inert solids resulting from high streamflow velocity (Chisholm and Downs 1978). The benthic community in these streams are usually more sensitive to stress from sediment loading than are those of an agricultural region. Streams having these characteristics can be found in several areas of New York and Pennsylvania and must be considered sensitive habitats. State-of-the-art erosion control techniques--e.g., straw bales used as filters, sediment holding ponds, and diversion ditches--can minimize solids loadings to these streams from construction activities.

4.042
The exposure concentrations of chemicals associated with drilling activities--e.g., liquid hydrocarbons, brines, and metals in drilling fluids--can usually be estimated from the physicochemical properties of the substance and its bioactivity. Chemicals with high vapor pressures and low solubilities (hydrocarbons) tend to migrate toward the atmosphere; those with low vapor pressures and low solubility (some metals) become associated with the sediments. The movement and accumulation of these sedimented chemicals is thus influenced by stream dynamics. The remaining chemicals that have a high solubility remain in the water and are subject to rapid dispersion, the magnitude of which depends on the size of the receiving water (Baughman and Lassiter 1978).

4.043
The release of chemicals during a drilling operation can result from several activities, from actual drilling to production. The magnitude of the impact of these releases on macroinvertebrate communities depends upon the factors listed in Table 4-7. Most of the streams in the Lake Erie watershed from New York to Ohio are slow-moving watercourses through agricultural regions. The physical characteristics of these bodies of water would suggest that the effect of a release, subject to the amount released, would not be widespread although local impacts may be severe. However, the overall impact of any chemicals introduced into an aquatic habitat must consider siting and seasonal considerations to delineate how much of a potential pollutant will reach the aquatic habitat and under what conditions. In addition, a small impact to a lower trophic level (macroinvertebrates) may result in a more severe impact to higher levels (fish), from bioconcentration* of contaminants and alterations of food organism communities.

4.044
The withdrawal of water from flowing aquatic habitats for drilling activities constitutes a source of impact from habitat modification. Although the impact

*Absence of professional consistency in definition of bioaccumulation, bioconcentration, and biomagnification has resulted in the presentation of a simplified interpretation of the concept of pollutant movement from the environment into organism tissues; this concept is represented in this report by the term "bioconcentration". No distinction is made as to whether the pollutant concentration in organismal tissue is greater than the concentration of the pollutant in the environment or whether the pollutant could be transferred through the food web to other organisms.

from removal of water from a stream diminishes with increasing distance from the point of withdrawal, unless an additional source of water exists as tributary inflows, a reduction in the amount of habitat may occur. Sessile organisms in shallow riffle areas may be subjected to dessication, whereas more mobile macroinvertebrates in these same areas may decrease as a result of increased invertebrate drift. The impact of water removal on macroinvertebrates is thus reflected in changes in population size and species composition. These changes may influence higher trophic levels that utilize macroinvertebrates as a food source.

4.045
The magnitude of the impact of water withdrawal on macroinvertebrates in flowing and nonflowing aquatic ecosystems depends upon many factors (see Table 4-7), especially the frequency of withdrawal and volume of water in the aquatic habitat subjected to withdrawal. Most of the streams in the Lake Erie watershed are small and maintained by seasonal base flow. Although these streams may be adversely impacted for brief periods, recolonization of affected areas is expected to be rapid and no long-term impacts are anticipated.

Impact Assessment--Fish

Impacts of the Reference Program

4.046
Resuspension of sediment from jacking down was investigated as a potential source of impact to fishes due to the amount of material introduced into the water column (Table 4-4). Dredging and/or construction operations at new or existing harbor facilities would also be a potential source of impact to fishes through sediment resuspensions. Impacts to fishes from suspended solids and sedimentation include interference with normal gas exchange in the gills, physical damage to gill filaments, smothering of fish eggs, smothering of benthic food organisms, and alteration of benthic habitat (Ellis 1944; Wallen 1951; Horkel and Pearson 1976; Schubel et al. 1973). In addition, there is also the potential impact of bioconcentration of contaminants in fishes. Lake Erie sediments contain elevated concentrations of heavy metals and chlorinated hydrocarbons (Kemp et al. 1976; Kemp and Thomas 1976; Walters et al. 1974; Konasewich et al. 1978). Ingestion of particulate matter with adsorbed contaminants could occur when fish actively feed on benthic organisms suspended along with bottom sediments.

4.047
However, after investigation of the nature and magnitude of resuspended sediments resulting from Reference Program activities, it was concluded that only minor impacts would occur; impacts to fishes from resuspension of bottom sediments would be local and temporary, occurring in the vicinity of the rig. The buffer zone restricting any drilling activities within one mile from shore will protect most fish spawning areas from the effects of sediment resuspension consequent to moving offsite. On a far field, lakewide, or annual basis, the reintroduction of sediment is insignificant compared to other sources. The net annual sediment loading to Lake Erie has been estimated at 14.3×10^6 MT (15.8×10^6 short tons) (Kemp et al. 1977) or approximately 350 times the amount of sediment resuspended by jacking down during the years with maximum drilling (1985-1988). Considering the short duration of exposure to resuspended sediment (see Table 4-4) and the dispersion of materials by currents,

the probability of any significant bioconcentration of contaminants by fish is low. If the Reference Program is approved in principle, the Corps and USEPA may require operators filing for federal permits to provide site-specific data--e.g., bottom topography, physical and chemical properties of sediments, bioassays, sediment depth, and, if possible, a determination of the source of the sediment--needed for assessment of potential impacts to fishes from proposed development procedures.

4.048
Trenching the lake bottom for pipeline burial will cause some degree of habitat alteration. Assuming that there are 10 landfalls and that pipeline trenching will be required within the 30-ft contours (approximately one mile from contour to shore), approximately 16 x 10^4 ft^2 will be disrupted by digging a trench 3 ft wide. If sedimentation affects an additional 3 ft on each side of the trench, the amount of benthic habitat affected triples.

4.049
Well stimulation returns and well decommissioning fluids are considered a potential impact source because of the uncertainty of their magnitude and composition. The total quantities produced with typical Reference Program wells and the chemical composition of representative fluid components are presented in Tables 1-29 and 1-30, respectively. Some of the components of the stimulation mixture are toxic to fish, e.g., acid, surfactants, and fracturing compounds; toxic concentrations of some of these additives (e.g., non-ionic detergents) are on the order of 50 ppm or less (Borodczak 1968). What chemical reactions occur under stimulation pressures and conditions or through time are not known. Toxic concentrations could occur close to the discharge. Dispersion of chemical additions by lake currents would reduce their potential toxicity substantially within a short distance from the outflow. However, since some of the pollutants released during well stimulation may be toxic, the concentrations at which stimulation fluid components are released will be controlled by an NPDES permit. Releases should be limited to levels at which toxic impacts do not occur and such that best available technology is applied. Total or annual inputs and effects on a lakewide basis would be undetectable.

Impacts of the Onland Alternative Program

4.050
Sedimentation and high levels of suspended solids can have several effects on fishes depending on the magnitude of material entering the water body. Suspended solids can abrade or clog fish gills causing an increase in mucous production; this increased mucous can, in turn, interfere with respiration by impeding oxygen exchange (Ellis 1937, 1944; Wallen 1951; Horkel and Pearson 1976). Larval fishes may be more severely affected because many lack the ability to shed particles from their gills by mucous secretion (Everhart and Duchrow 1970). Sediment can also smother fish eggs laid on stream or pond bottoms, increase oxygen demand, and reduce populations of invertebrate food organisms by modifying their benthic habitat (Cordone and Kelley 1961).

4.051
Chemical additions to aquatic resources can potentially have many effects. In sufficient quantity, some chemical additions may produce concentrations toxic to aquatic life. In lesser concentrations, some chemicals may have any or all

of a multitude of sublethal effects. These have been reviewed by Sprague (1971) and include interference with enzyme activity; inhibition of neurophysiological activity; increased susceptibility to diseases, parasites, and predation; and reduced growth survival, fecundity, and fitness. Additionally, some chemicals may be subject to bioconcentration in fishes. The severity and significance of the consequences of chemical additions depend on a number of modifying parameters (Table 4-7). Some chemicals in small concentrations are avoided by fish, e.g., migrating salmonids (Saunders and Sprague 1967). The presence of potentially toxic chemicals in fishes not only reduces their viability but also their value and desirability as sport or commercial species.

4.052
Water withdrawal from small ponds and streams to provide drilling fluid could have major consequences depending on the size and type of water source. (Water withdrawal requirements were discussed in Chapter Two - Description of the Onland Alternative Program, Onland Development.) Removal of water will reduce the size of the water body and reduce or modify the available habitats. Small ponds and streams are particularly sensitive.

4.053
In small streams, flow provides n.t only living space for fishes but also carries food organisms as drift to fishes. Reduction of flow or discharge volume will concentrate aquatic organisms and increase competition for food, space, and available shelter. Reduced living space may increase the behavioral interactions of territorial species, and territory defense results in the expenditure of energy that could otherwise have been used for growth or reproduction. Withdrawal of water from a stream will also remove drifting or planktonic fish food organisms; reduction of discharge volume will decrease the power of the stream to dislodge and carry drifting fish food organisms.

4.054
In a pond, reduction of the volume of water will decrease the amount of potential living space for fish, reduce the amount of protective cover for small or young fish, and reduce the amount of habitat available for fish food organisms. Competition may increase, as may predator-prey interactions until the community has adjusted its numbers to the new carrying capacity of the system.

Impacts of Accidents

4.055
Reference Program accidents are potential impact sources to phytoplankton, invertebrates, and fish. The magnitude of impact will depend on several factors including the kinds and amount of materials which enter the Lake, the types and number of invertebrates and fish in the vicinity of the rig, and the meteorological and limnological conditions at the time of the accident.

4.056
Assumptions used to model accidental releases of critical Reference Program materials and residuals are summarized in Appendix C. Predicted worst-case concentrations at the point of discharge and after 0.5 mile of pollutant dispersion are presented in Table 4-5. This table also provides a comparison of predicted concentrations in receiving water to quality criteria for freshwater aquatic life. Accidents are further characterized and consequential water quality impacts are discussed in Chapter Four - Water Quality.

4.057
Although the potential for impacts to phytoplankton, invertebrates, and fish exposed to accidental releases of materials is high in the immediate area of the accident, the effects of an accident at the population level would probably not be detectable. Impacts from accidents would be local and insignificant on a lakewide or annual basis.

WATER USE

Impact Sources

4.058
Activities of the Reference Program and Onland Alternative Program that might impact water use are the same as those listed as potential impact sources to water quality, aquatic biota, land use, and esthetic values. Commercial fishing could be impacted by the presence of bottom obstructions at completed wellheads and the exclusion of commercial fishing in small localized areas during drilling. Potential sources of impact to Lake Erie ports, shipping, and navigation due to the Reference Program vessels include: temporary obstructions to navigation; increased lake and port traffic; and competitive use of port facilities (such as harbors, docks, wharves or piers) and space for maintenance, repair, and storage. Other potential sources of impact due to the Reference Program include: competitive use of port facilities such as warehouses for storage, materials transfer, and maintenance; dockyard facilities for loading and unloading materials and equipment; and yards for construction of pipe assemblies, storage, materials transfer, and maintenance.

Impacts to Recreation

4.059
Reference Program activities could adversely affect recreational use of beach areas due to impacts to water quality, shoreline stability, shoreland use, and the visual environment of the shoreline. Impacts on these environmental qualities are predicted to be slight. Pipeline corridors might provide additional access to beach areas. Increased commercial use of the Lake and its harbors could increase hazards to recreational boating. The presence of drilling rigs, service vessels, tugs, and barges in the Lake would slightly degrade the "open sea" character of the Lake.

4.060
The Onland Alternative Program does not restrict drilling in onshore areas. Any such development could produce conflicts with recreational use.

Impacts to Lake Erie Fisheries

4.061
No detectable impacts to Lake Erie fish populations are projected to occur from gas development in the Lake. Impacts would occur but not of sufficient magnitude to be detected at the population level compared to changes in stock size arising from natural causes. Impacts to the commercial fishery would result from loss of gear through entanglement on wellheads and possibly temporary competitive exclusion from a specific fishing location due to the presence of a drilling rig. However, most commercial fishing occurs in the nearshore area where drilling is excluded. In the event of an underwater natural gas

flowline rupture--with release of potentially explosive and/or toxic (H_2S laden) gas to the lake surface in areas of commercial fishing, there could be a need to temporarily suspend fishing in the local area until the release could be stopped and gases allowed to disperse. This accident would be infrequent and the consequent suspension of short duration. The Onland Alternative Program would not directly impact Lake Erie fisheries since drilling would not occur there.

Impacts to Ports, Shipping, and Navigation

Reference Program

4.062
The maximum number of vessels committed to the Reference Program includes eight drilling rigs, three stimulation barges, three pipe barges, eight service vessels, and three tow tugs. The maximum assumed number of drilling rigs, stimulation barges, and pipe barges operating during a 214-day drilling season and supported by one shore-to-rig or shore-to-barge service vessel trip per day, would result in approximately 3000 dockages during the peak drilling season. This is about a 21% increase in Lake Erie inbound traffic beyond the total volume (14,000) reported for 1977 (Table 3-8), i.e., approximately 17,000 inbound vessels; however, the increased total volume of inbound traffic is still comparable to the ship volume handled in Lake Erie ports without U.S. gas resource development during the early 1970s (Table 3-7). Existing port facilities in the Lake Erie region--harbors, docks, wharves or piers, and space for maintenance, repairs, and storage--will be able to absorb peak vessel traffic increases attributable to the Reference Program.

4.063
One of the major problems for Ohio Great Lakes ports is competition with other Great Lakes ports for business (Vogel 1977). Schenker et al. (1976) reported that, due to concentration of commercial shipping traffic at more specialized ports, the smaller ports may not survive. Smaller ports, however, could adapt to new or expanded roles other than large-scale commercial shipping. Thus, it appears that increased traffic due to Lake Erie natural gas development should have a temporary beneficial impact on Lake Erie port facilities.

4.064
During the early 1970s, port facilities were available for peak traffic which exceeded projected levels during the drilling program. Thus, port facilities such as warehouses for storage, materials transfer, and maintenance; dockyard facilities for loading and unloading materials and equipment; and yards for construction of pipe assemblies, storage, materials transfer, and maintenance will be available for Lake Erie natural gas development activities. Additionally, Schenker et al. (1976) reported that concentration of shipping activities at fewer but more specialized ports and industrial demand for extensive and peripheral sites, rather than central and intensive sites, will decrease waterfront use by port activities or by bulk-receiving and bulk-shipping industries.

4.065
Service port selection by operators will depend on presence and availability of harbor facilities. Although it is difficult to predict with certainty which ports would be selected as service centers during Lake Erie natural gas

development, Buffalo, Erie, and Cleveland are likely candidates for drilling in New York, Pennsylvania, and Ohio waters, respectively, because of their excellent port facilities. At least one more Ohio port probably would be used as a service center.

4.066
Despite lack of rig mobility while drilling, visual and audible warning devices should effectively reduce potential for rig-vessel collisions (McGregor et al. 1978). Mariners are advised where gas drilling rigs are temporarily located in Lake Erie and that they are equipped with audible and visual warning devices. Additionally, the one-mile nearshore buffer zone assumed for the Reference Program would alleviate potential navigation congestion around harbors.

4.067
The likelihood of a gas well or pipeline being snagged and broken by an anchor appears minimal. Wells are prohibited from the nearshore zone; pipelines will be buried in 5 to 10 ft of lake sediments within the 30-ft water depth contour and, consequently, should remain protected against anchors dropped from recreational boats that frequent nearshore waters. Large commercial vessels avoid nearshore waters at all times except when entering harbors through maintained channels.

4.068
Reference Program wellheads will be buried below lakebed depth wherever possible to avoid anchor snags. The need for pipeline burial in water depths greater than 30 ft was investigated in response to a proposed Pennsylvania offshore lease requirement stating that "all pipelines under shipping lanes and anchorages must be buried" (Pa. Dep. Environ. Resour. 1977). There are no official designated anchorages in U.S. Lake Erie waters approved for development, and courses used by commercial vessels can deviate from conventional lanes in inclement weather; commercial vessels avoid anchoring in the open Lake under any conditions. Anchors from large vessels will penetrate into all but the hardest consolidated sediments and exposed bedrock, requiring deep-water pipelines to be buried beneath greater than 5 to 10 ft of sediments to ensure adequate protection against snags. The marginal protection offered from burial of pipelines in water depths greater than 30 ft does not warrant the added costs of trenching.

4.069
Designation of pipelines and wellheads on NOAA navigation charts should serve as adequate warning to vessel pilots. Currently, Great Lakes Navigational Charts (U.S. Dep. Comm. 1978) warn Lake Erie captains and pilots about the potential hazards posed by all underwater structures including Canadian natural gas structures submerged beneath Lake Erie:

> "Gas pipelines and wells contain natural gas under pressure and damage to these installations would create an immediate fire hazard. Vessels anchoring in Lake Erie should do so with caution after noting the underwater, and therefore concealed, positions of all oil and gas wells, pipelines, submerged cables and other installations."

Presumably, future editions of navigational charts for Lake Erie could be updated with exact locations of U.S. program installations in the event that offshore natural gas development is approved.

Onland Alternative Program

4.070
It is assumed that the Onland Alternative Program would not adversely impact present utilization patterns of ports, shipping, and navigation on Lake Erie, since a well developed land-based transportation system is present in the region to provide delivery of materials and services to drilling locations.

Municipal/Industrial Water Supplies

4.071
In the Reference Program, drilling operations may not take place within 0.5 mile of potable water intakes. Also, gas pipelines will be excluded within 0.5 mile of potable water intakes. At this distance, concentrations of suspended solids generated from routine drilling operations will not exceed 10 mg/L at the intake. Using coagulation and filtration, water treatment plants are able to remove suspended solids at concentrations up to 100 mg/L (USEPA 1977c). Therefore, the small concentrations released during routine operations will not cause a problem for municipal and industrial users.

4.072
Contaminants released during an accident that may threaten water supplies are listed in Table 4-8. The maximum contaminant level is defined as the largest allowable concentration of a particular substance in the water supplied to consumers following treatment (USEPA 1976a). At 0.5 mile from the point of release, the concentrations of barium, chromium, chloride, and surfactants are below maximum contaminant levels; these concentrations should not be harmful in potable water supplies. Hydrogen sulfide will produce an objectionable odor at 0.1 mg/L. However, at the treatment plant, hydrogen sulfide will be oxidized by chlorine, forming free sulfur or dilute sulfuric acid (White 1972).

4.073
In the case of a pipeline break, di- or triethylene glycol may appear at potable water intakes at concentrations up to 1 mg/L. There are no drinking

Table 4-8. Contaminants Released During Accidents

Contaminant	Source	Maximum Concentration 0.5 mi from Release (mg/L)	Maximum Allowable Contaminant Level (mg/L)
Barium	Rig capsize	0.018	1.0[a]
Chromium	Rig capsize	0.00009	0.01[a]
Chloride	Rig or barge capsize	0.23	250[b]
Hydrogen sulfide	Pipeline break	0.1	0.05[b]
Surfactants (foaming agents)	Barge capsize	0.0004	0.5[b]
Polyethylene glycol	Pipeline break	1.0	Not available

[a]Data from USEPA (1976a).

[b]Data from USEPA (1977b).

water standards for polymeric ethylene glycols. However, ambient level water quality goals for the monomer, ethylene glycol, have been set at 140 μg/L (Cleland and Kingsbury 1977). The method generally used for treatment of organics in water purification facilities is activated carbon adsorption, which has low removal efficiencies for glycols (Nakano et al. 1976; Zeitoun and McIlhenny 1971). Although the levels of polyethylene glycols from a pipeline break are relatively harmless, glycols can easily form chlorinated hydrocarbons (Krespan 1975; Natl. Acad. Sci. 1979). Because chlorinated hydrocarbons are known carcinogens, the direct chlorination of glycols at a water treatment plant is a potential threat to the consumer (Natl. Res. Counc. 1977). The primary drinking water standards specifically restrict the concentration of six organic compounds; all six compounds are chlorinated organics, with maximum contaminant levels in the range of 0.1 to 0.0002 mg/L (USEPA 1976a). However, the restricted compounds are commercial biocides with known toxicity levels. The carcinogenicity and/or toxicity of the products of the reaction between aqueous chlorine and polyethylene glycol as compared to the restricted compounds is presently unknown. As indicated in Table 4-5 and Appendix C, an accident involving breakage of a glycol line is anticipated to be a low-frequency event lasting about one day. This worst-case event also assumes failure of installed control equipment, i.e., the safety valve. Should gas development in Lake Erie be found acceptable in principle, the above factors should be taken into consideration by water quality agencies when determining if further investigation of the products of reaction between aqueous chlorine and polyethylene glycol is warranted.

Municipal/Industrial Wastewater Disposal

4.074
Drilling is restricted to distances of at least 1000 ft from any outfall (see Table 1-7). Dispersion and naturally occurring chlorine demand will reduce chlorine from municipal, industrial, and power industry effluents to concentrations that are not measurable. As a result, interactions between waste effluents and releases during drilling should not cause a significant impact.

TERRESTRIAL ECOLOGY

Impact Sources

4.075
Activities of the Reference Program and the Onland Alternative Program which potentially could impact terrestrial ecology are summarized in Table 4-9. Wetlands, important tributary streams, and ecological resource areas have been precluded from use as landfalls on the basis of environmental or regulatory restrictions as described in Table 1-7.

Impacts of the Reference Program

4.076
The major impact on terrestrial systems would be that associated with land clearing for the pipeline landfalls, onshore gas processing and treatment facilities, and connecting pipelines to existing gas transmission pipelines. Significance of the loss of vegetation and wildlife would depend on site-specific characteristics. This loss would persist for the life of the project in pipeline areas and would be permanent in the case of production facilities.

Table 4-9. Summary of Possible Sources of Impacts to Terrestrial Ecology from Activities Related to Natural Gas Development

Program Phase	Activity: Reference Program	Activity: Onland Alternative Program
I. Exploration and development	Construction of landfalls, pipelines, and production facilities Construction and operation of new waste-treatment/disposal facilities	Site preparation Water withdrawal for rig use Discharge of fluids and gases to atmosphere Construction of pipelines Accidental spills of fluids from rig or mud pit
II. Production	Maintenance of pipeline right-of-way Pipeline rupture Construction and operation of new waste-treatment/disposal facilities	Maintenance of pipeline right-of-way Pipeline rupture
III. Decommissioning	Removal of pipelines at landfalls	Removal or abandonment of pipelines

Even with careful siting and proper construction controls, there would be some problems with soil, bluff, and beach erosion at one or more of the sites. This would require proper controls, including revegetation techniques. These techniques are within the realm of state-of-the-art construction practices. However, these practices are not always implemented because of cost and time constraints (Beasley 1972; USEPA 1973a). The loss of the soil due to erosion is irretrievable.

4.077
On pipeline rights-of-way, the specific maintenance procedures employed may vary greatly from one company to the next and from one state to the next. The traditional method of maintaining a low grass-forb cover over buried pipelines by periodic broadcast application of herbicides can have deleterious effects on surrounding vegetation from the herbicides. Herbicide use can result in the maintenance of an early successional community with few species of plants and animals. On the other hand, if selective vegetation management methods are employed (Egler and Foote 1975a, 1975b), the use of herbicides can be drastically reduced, and a more diverse and stable community could develop.

4.078
Construction of new waste-treatment/disposal facilities would preempt the further use of that land for wildlife habitat unless and until that land could be reclaimed. Based on Reference Program assumptions, land will be required

for treatment facilities (liquid/solids separation ponds) and landfills (see Figure 1-16). Assuming that one treatment facility (approximately 10 acres in size) is located in the vicinity of each of the three major harbors used for offshore activities, approximately 30 acres would be devoted to treatment of wastes. The total volume of wastes requiring landfill space will be less than the total waste volume (1100 acre-feet, excluding domestic wastes [Table 1-31]) because liquids can be separated and disposed of through onland spraying or other suitable techniques not requiring long-term commitments of land. The total volume of land preempted is insignificant on a regional scale and is less important than the location of the land. To avoid environmentally sensitive areas, state-of-the-art site suitability/constraint analysis techniques will be required to locate treatment facilities and any new landfills.

4.079
Impacts could also occur from the operation of treatment facilities. There is a possibility for wildlife to ingest or otherwise be affected by compounds contained in uncovered wastes. For example, liquid/solids separation ponds could be utilized by waterfowl, shorebirds, and mammals. If this proves to be a problem through experience, techniques useful for enclosing these fenced treatment facilities, e.g., overhead netting, will have to be investigated. The potential for uptake of heavy metals by vegetation growing on or around treatment/disposal facilities and consequent problems caused by transmission of elements upward through the food web can be minimized by utilizing facility design principles required by RCRA.

4.080
The regional terrestrial impacts associated with the Reference Program would be insignificant, primarily due to the fact that relatively little land would be disturbed. Also, most of the land would be located in the already disturbed coastal zone. In the other areas, most of the land is cropland. Only in the scattered seminatural areas would there be a net loss of these areas. This loss is insignificant compared with losses associated with summer home, highway, residential, commercial, and industrial expansion in the coastal zone.

Impacts of the Onland Alternative Program

4.081
For the Onland Alternative Program, terrestrial impacts may be locally significant. A wide variety of soils, topography, biota, and local climate exist throughout the region. Also, specific land clearing, drilling, construction, and maintenance methods vary from one company to the next and from one state regulatory system to the next. The magnitude and acceptability of impacts would vary accordingly. However, some generalizations can be drawn regarding potential risks to terrestrial systems and the relative significance of these risks.

4.082
The first group of impacts would occur at the drilling site. Although the site is relatively small (3 acres), land will be cleared and graded both at the site proper and along the access road. In the western part of the Onland Alternative Study Region, these roads should be short and flat (because the existing network of both primary and secondary roads is well developed and the topography is gentle). In the eastern part of the region in hilly forested areas, however, access roads may be longer and more difficult to construct.

Timber harvesting haul roads, which can cover 10-15% of a forested area, may sometimes be used with upgrading, but where such roads do not exist, roads and rights-of-way may have to be constructed. Under these conditions, more habitat may be disturbed for the access road than at the drilling site proper. Also, whereas in the farming areas the drilling access road may be temporary and the land restored after drilling, in the forested areas the road may become permanent due to erosion or continued use for recreational access. Although this in itself would not be a significant impact in the forested areas compared to logging haul and skid trails, it would nonetheless be an incremental commitment of land.

4.083
Another potential impact at the drilling site is defoliation of nearby vegetation during venting of gases and liquids to the atmosphere. When the well is stimulated, and after collection of most of the return fluids, the well is open-flow tested for up to 12 hours. Most of the returning fluids and gases would be in a foam that is finally diverted to a big trench. However, some mist would be vented to the atmosphere. This mist is essentially very small liquid droplets entrained in the gas. Nearby vegetation may be damaged by some substances in the mist, including sulfur compounds (H_2S is especially high in Ohio gas produced from the Lockport Formation), acid, saline liquids (brines from the producing formation), or liquid hydrocarbons. Although vegetation defoliation is not expected to be common, it would likely occur at a few wells. Vegetation destruction would result in loss of wildlife habitat.

4.084
A local and possibly significant impact near the well site is related to the use of water for drilling. If a surface water body is nearby (within approximately 0.5 mile), a surface pipe will be run to that water. In a few cases, wetlands are likely to be associated with this water. Depending on how much water is withdrawn, the size of the water body, and the time of year, withdrawal can have a temporary deleterious impact on plants and animals.

4.085
Other potential impacts at the wellsite are those associated with accidents. The most common and frequent accidents would be spills of chemicals, muds, oils, drilling fluids, etc. Although most of these spills would be contained and cleaned up, some would not and would contaminate the soils and possibly affect nearby vegetation. A second type of accident is related to failure of the blowout preventers. The problem of the mist defoliating nearby vegetation would be similar to that discussed earlier for open-flow testing, but the duration of the misting may be several days, thus making the impact more severe. Also, if oil is encountered along with the gas (production of oil plus gas is allowed onland), the impact of spills would be greater and possibly more lasting. Another potential problem is associated with the mud pit, which is effectively a catch-basin for many types of liquid and solid wastes. During an extreme rainfall event, the pit might overflow and contaminants would seep into the soils. The risk of this potential impact can be minimized by proper sizing of the pit and proper diversion of runoff around the pit. In summary, there are several accident scenarios at the wellsite which could lead to destruction of wildlife habitat through contamination of the soil and defoliation of nearby vegetation. The toxicity of the various pollutants to vegetation and the inefficiency of present cleanup techniques (Pa. Gov. Off. State Plan. Dev. 1976a) makes onland accidents an environmental risk.

4.086
Both in the flat farming areas and in the steep forested areas, soil would erode along the pipeline rights-of-way. The entire region is subject to soil erosion problems. Proper routing, construction, timing, and prompt revegetation can minimize the problems (Beasley 1972; USEPA 1973a). For the Onland Alternative Program, many miles of pipeline would be constructed throughout the region and various companies and states would be involved. Erosion control practices vary. Plans to limit construction to certain times of the year or plans for prompt revegetation may fall by the wayside due to slippage of schedules for materials delivery or availability of equipment and personnel. Additionally, revegetation success would be influenced by climatic conditions. Thus, although erosion can be minimized with state-of-the-art controls, there would likely be some local problems that are unavoidable along some stretches of pipeline. On the other hand, on some of the cropland there may be less soil erosion during the year the land is disturbed for natural gas development than would normally occur under routine cultivation practices.

4.087
As discussed for the Reference Program, right-of-way maintenance procedures would vary, and thus the impacts would also vary. However, for the Onland Alternative Program, much more land would be used for rights-of-way, and more forested and "natural" areas would be traversed because of the diffuse nature of the wellsites. A few wetlands may have to be crossed (the impacts of wetland pipeline construction would probably be minimal as long as usual construction methods are employed) (Darnell et al. 1976). Although the Onland Alternative Program pipelines would be a small fraction of existing and future rights-of-way in the region, impacts would be incremental.

4.088
Another impact associated with pipelines is that they would allow effective, albeit illegal, access to private land and to remote public lands. While this may be desirable in some cases [e.g., access for hikers and cross-country skiers in public recreation areas (N.Y. State Parks Rec. 1972)], it may be very undesirable when off-road vehicles (ORVs), including snowmobiles and dirt bikes, use the rights-of-way. The ORVs strip vegetation, cause soil erosion and compaction, disturb fragile and unique ecosystems (stream banks, meadows, bogs, etc.), and directly kill or disturb wildlife (noise and harassment) (Sheridan 1979). It has been noted that remnant wild and semiwild areas near urban environments have been particularly hard hit. This is especially relevant to the Onland Alternative Study Region where more strict regulations of ORVs are needed to prevent damage to fragile habitats (Great Lakes Basin Comm. 1975c). Although fallen trees, fences, etc., on the pipeline rights-of-way can be used to control ORV access, it is likely that in most cases these controls would not be effective. Without stricter regulation of ORVs and strong enforcement of the regulations, this would be an unavoidable adverse impact associated with the Onland Alternative Program.

4.089
It is difficult to compare the risks and impacts of onland pipeline accidents with such accidents in the Lake. The causes, frequency, and severity of breaks onland would be different (e.g., breaks caused by machinery, leaks causing explosions, and placement and numbers of shutoff valves will be different). Also, transport of any substances which escape from the broken line and affected ecosystems would be different. Generally, only nearby land would be

affected. Since there are no effective cleanup methods, contamination of terrestrial systems would be unavoidable. If the accident occurred in an ecologically sensitive area, the impact might be significant. This is an environmental risk associated with the Onland Alternative Program that is substantially different in nature and consequences from the Reference Program.

ENDANGERED SPECIES

4.090
It is probable that endangered, rare, or threatened species will be adversely affected by activities of either the Reference Program or the Onland Alternative Program through either direct or indirect alteration of habitat. The tradeoff is: (1) the remotely possible adverse direct effects on fish in Lake Erie plus minutely incremental destruction of eagle and other bird habitat along the shoreline for the Reference Program, versus (2) the highly probable adverse direct effects on some plants, birds, fishes, and other species somewhere in the Lake Erie region plus the incremental destruction of habitat for the Onland Alternative Program. Onland Alternative Program impacts would be site-specific.

LAND USE

Impact Sources

4.091
Activities of the Reference Program and Onland Alternative Program that potentially could have impacts to land use are summarized in Table 4-10. Harbors, public beaches, and other areas have been precluded from use as landfalls on the basis of environmental or regulatory restrictions.

Impacts of the Reference Program

4.092
Landfalls pose land-use conflicts because of limited shoreline access. Most of the shoreland is presently used for public lands, and for residential, commercial, and industrial development. Although it will likely be difficult to obtain access through residential areas, it may be possible to gain the necessary 30- to 50-ft right-of-way through undeveloped commercial or industrial land, possibly on a joint-use basis. In the other shoreline areas, particularly in the agricultural and undeveloped lands along the eastern Pennsylvania and New York shore, the high bluffs make access difficult. Since public access to the Lake is a problem in the Reference Program Study Region, it may be possible to arrange for public use of the gas pipeline access. For example, the Pennsylvania Coastal Zone Management Plan lists development of new manufacturing activities which permit access to the Lake as a high priority activity in development areas (Pa. Dep. Environ. Resour. 1978). Furthermore, provision of fishing and boating facilities may alleviate public resistance to pipeline landfalls.

4.093
Impacts associated with siting, construction, and operation of gas production facilities (located within 0.5 mile from the shoreline) are similar to impacts related to landfalls. However, there may be more flexibility in siting these facilities because of the less intense competition for land. With due consideration of technical constraints, e.g., necessary pipeline pressures,

Table 4-10. Summary of Possible Sources of Impacts to Land Use from Activities Related to Natural Gas Development

Program Phase	Activity: Reference Program	Activity: Onland Alternative Program
I. Exploration and development	Construction of landfalls	Sites for drilling rigs, roads, and pipelines
	Disposal of drill cuttings and drill fluids	
	Noise generated from construction and operation of facilities	Noise generated from construction and operation of facilities
II. Production	Sites for production facilities	Sites for production facilities
	Noise generated from construction and operation of facilities	Noise generated from construction and operation of facilities
III. Decommissioning	Removal of pipelines	Removal or abandonment of pipelines
		Abandonment of wells

setback of production facilities from the shoreline would help mitigate impacts in the coastal zone. There will be additional land-use conflicts in the special farming areas (orchards and vineyards) east of Erie. Orchards and vineyards are considered to be unique, and owners of these lands have traditionally resisted development pressures. In farmland, the pipelines are generally buried sufficiently deep so as to not interfere with agricultural machinery. If topsoil is segregated and replaced after backfill, productivity losses should be negligible.

4.094
Construction and operation of gas process and treatment facilities and operation of offshore equipment can generate noise. The degree to which this noise will cause adverse environmental impact is dependent upon the timing and nature of the noise, degree of control technology employed, characteristic surrounding land use, and physical features of the environment that can act to attenuate (lessen the intensity of) the noise as it travels away from its source.

4.095
Noise will be generated from equipment used to construct all Reference Program facilities, e.g., pipelines, waste treatment/disposal facilities, gas production plants and harbor facilities. Table 4-11 is a summary of decibel levels recorded at 50 ft from various pieces of operating construction equipment; the distance required to attenuate the generated noise to ambient levels (rural, 40 decibels; metropolitan, 70 decibels) is also given. Attenuation distance was estimated using a rule-of-thumb calculation that decreases noise

levels by six decibels for each time the distance from the source is doubled (USEPA 1973b). Control methods such as mufflers, intake silencers, and engine enclosures currently exist that can potentially reduce noise levels from 5 to 10 decibels beyond those listed in Table 4-12 (New Engl. River Basins

Table 4-11. Noisiest Equipment Operating at Construction Sites[a]

Construction Phase	Equipment	Decibel Level at 50 ft	Attenuation Distance (ft)[b] Rural Area (40 dB)	Metropolitan Area (70 dB)
Ground clearing	Truck	91	13,000	600
	Scraper	88	10,000	400
Excavation	Rock drill	98	25,600	1,200
	Truck	91	13,000	600
Foundations	Jack hammer	88	10,000	400
	Concrete mixer	85	6,400	300
Erection	Derrick crane	88	10,000	400
	Jack hammer	88	10,000	400
Finishing	Rock drill	98	25,600	1,200
	Truck	91	13,000	600

[a] Data from U.S. Environmental Protection Agency (1971).

[b] These calculations do not take into account physical barriers, terrain, vegetation, and other factors that lower sound levels within a shorter distance.

Table 4-12. Sources of Noise in Gas Plants[a]

Source	Decibel Level	Control Technology
Compressor	92-100 at operator's position	Muffler; enclosure of equipment
Boiler	90 at 6 ft	Muffler
Flarestacks	81-96 at 20 ft	Multiport injector systems
Mechanical scrubbers	No data to date	

[a] Data from Goodfriend Associates (1971).

Comm. 1976). Most of the Reference Program construction requirements in rural, low ambient-noise areas will center on pipelines and gas production plants. Under Reference Program assumptions, the number of pipelines and corresponding plants will be limited to 10. Project construction timing should be limited to a few months. Most construction should occur during the growing season when vegetation can provide maximum noise buffering. Provided that construction activities are restricted to reasonable work-day hours, noise should not be a significant problem in rural areas and even less noticeable in urban areas.

4.096
Offshore noise should be insignificant to people living, recreating, and working onshore because of the combined effects of noise control technologies, a prescribed mimimum one-mile buffer zone separating offshore activities from shore, the shoreline terrain and vegetational buffers, and the transient nature of offshore activities.

4.097
Gas production facilities contain various pieces of equipment (mainly compressors) that generate noise continuously (24 hours per day) during plant operation; noise levels and potential control technologies are summarized for unenclosed noise sources in Table 4-12. Also, annual pipeline and compressor venting lasting less than one hour can result in uncontrolled noise levels of 140 decibels at 100 ft from the source. Silencers are available to lower this level to 80 decibels (U.S. Dep. Inter. 1975). Noise generated from an unenclosed compressor operating at 100 decibels will attenuate to rural, ambient noise levels (40 decibels) in approximately one mile, according to the previously mentioned rule-of-thumb calculation. This distance will decrease using state-of-the-art noise control technologies, enclosures, and design principles to maximize terrain and vegetational buffering effects. Silencers built into the compressors can lower the noise level to between 56 and 61 decibels at 800 ft from the source (Fed. Power Comm. 1976). Consequently, whereas noise from gas production facilities should not cause significant problems in industrial areas, special design considerations will be required when production facilities are planned for rural settings. In all cases, noise from all Reference Program activities must be within limits established by local ordinances or regulations for protection of the environment and within limits established by regulations of the Occupational Health and Safety Act for protection of workers.

4.098
When gas production facilities are abandoned, the 3-10 acres devoted to buildings, storage facilities, pipelines, compressors, parking lots, and buffer zone will probably continue to be used for industrial purposes (especially if a zoning status change was required for the original development of these facilities). If the facilities are dismantled and removed, the land may remain in industrial use or it may change to some other use. Erosional degradation and/or removal of topsoil during construction could decrease the site's future agricultural potential.

4.099
It is expected that only a small number of other lakeshore facilities--such as temporary service bases, repair and maintenance yards, pipe coating yards, and pipeline installation bases--will be required in the Reference Program. These facilities can probably be located at existing dock facilities, railroad yards, etc. Impact associated with these facilities would be insignificant.

4.100
Although it is recognized that Lake Erie natural gas drilling is a controversial environmental issue relative to development in the coastal zone (Pa. Dep. Environ. Resour. 1978), it is also recognized that such development can have benefits and that coastal zone management (CZM) plans cannot summarily preclude this type of development. The Pennsylvania plan notes that the facilities for processing and distribution of the gas could be easily accommodated in the Erie port area (Pa. Dep. Environ. Resour. 1978). Also, while the CZM Act has a consistency requirement which mandates that federal agencies must make their activities consistent to the maximum extent practicable with state CZM programs (Dinkins 1977; Hildreth 1976), the act also mandates that the Secretary of Commerce cannot approve a plan (and thus allow the state to receive federal funds for implementation) unless the Secretary finds that the plan provides for "adequate consideration of the national interest involved in the siting of facilities necessary to meet requirements which are other than local in nature" (Rubin 1975; Hildreth 1976).

4.101
Another important land-use issue is the disposal of solid and liquid wastes, including drill cuttings and drilling fluids, generated by gas development in Lake Erie. Currently, there are no final EPA criteria that can be used to determine if the drilling wastes are hazardous. Ultimately, classification will be necessary to determine whether treated and untreated wastes can be disposed of in conventional or RCRA-approved landfills. Conventional landfill sites are limited in the Lake Erie region; sites for RCRA-approved landfills will be even more restricted.

Impacts of the Onland Alternative Program

4.102
Much more land would be needed for the Onland Alternative Program than for the Reference Program. Although many more types of land-use conflicts could be encountered for the Onland Alternative Program, constraints would generally be less severe, and it would be easier to avoid conflicts. Pipeline right-of-way routing problems will, however, be more extensive than those of the Reference Program due to the greater magnitude of land-based pipeline rights-of-way and the greater variety of land uses encountered. On the other hand, the siting of the gas processing and treatment facilities will be more flexible, since production facilities need not be confined to the vicinity of the lakeshore as in the Reference Program.

4.103
There are numerous, scattered, small, critical resource areas and public lands throughout the Onland Alternative Study Region. In addition, there is a large public area in the eastern part of the region in the Allegany State Park and Allegheny National Forest (Ohio Dep. Nat. Resour. 1975; Pa. Dep. Environ. Resour. 1976, 1978; Pa. Gov. Off. State Plan. Dev. 1976b; Great Lakes Basin Comm. 1975b; N.Y. State Parks Rec. 1972). Many of these areas are privately owned, but nonetheless the states desire that they be preserved. The states are just beginning to identify these areas, and control over them is far in the future. In the existing public lands, there is already gas and oil development and competition for various uses of the land (e.g., forestry, recreation, preservation of natural areas). Although the use of land for the various facilities for natural gas development may occur on, or conflict with other

uses of these areas, in many cases this can be avoided by careful siting of the facilities. Where it is unavoidable, special restrictions or limitations may allow for compatible use of the area by natural gas development without decreasing the unique or other values of the area. These conflicts can be resolved, and they may not even be significant when compared to other more serious development pressures in the Onland Alternative Study Region.

4.104
On forestlands, timber production will be lost at the gas production facilities, drilling sites, and pipeline rights-of-way for the lifetime of the facilities plus the time required for forest regeneration (over 50 years).

4.105
Development on prime farmland, although deplored, is not effectively controlled in the region (Pa. Dep. Environ. Resour. 1978). Except in areas with specialty crops, such as orchards and vineyards, impacts should be negligible. Prime farmland could be avoided, and, where necessary to drill or construct pipelines, replacement of topsoil and erosion control would mitigate impacts. If topsoil is segregated (both at the wellsite and along the pipeline trench) and replaced, long-term productivity should not be significantly decreased. The loss of one year's crop would be a short-term impact. In the western part of the region where the fields are tiled, productivity would drop where the tiles were not properly replaced or where new tiles were not placed across pipelines. Pipelines generally are buried sufficiently deep so as not to interfere with farm machinery.

4.106
There is a potential land-use conflict over erection of permanent facilities (e.g., gas processing and treatment plants or suspended pipelines) near and over state-designated scenic rivers (Ohio Dep. Nat. Resour. 1975). It may be perceived that the gas development would impair the scenic values of the rivers.

4.107
Use of the gas pipeline rights-of-way by off-road vehicles can cause conflicts with use of private lands both on and adjacent to the rights-of-way. This is considered to be a presently unavoidable adverse land-use impact of the Reference Program.

4.108
There will also be land-use impacts associated with the probable exercise of the right of eminent domain to obtain rights-of-way for pipelines where landowners refuse to agree to right-of-way leases or purchases. In some cases, conflicts can be avoided by rerouting, but this is more costly. Even where right-of-way access is voluntarily given, there will be restrictions on land uses during the life of the pipeline (e.g., building and vegetation restrictions). If the pipeline is simply abandoned after its useful life, there may be additional future costs and land use conflicts. If the pipeline is dug up and the land reclaimed, it can be returned to former or other uses.

AIR QUALITY

Impact Sources

4.109
Activities of the Reference Program and Onland Alternative Program that could impact air quality are summarized in Table 4-13. The reader is referred to Tables 1-25, 1-34, and 1-35 for more detailed presentations of Reference Program activities with potential air quality impacts. Source parameters and assumed worst-case meteorological conditions are given for all air quality parameter assessments where the assessment is quantitatively addressed. All predictions of pollutant concentrations are based on Turner workbook equations (Turner 1970).

Impacts of the Reference Program

4.110
Jack-up and floating rigs involved in exploration and development activities rely on similar power supplies for drilling and electrical power requirements. Each rig is equipped with two 600-700 hp diesel internal combustion engines. Under normal operation one engine will supply enough power to meet the rig requirements, with the other engine serving as a backup or emergency unit. Emission rates for individual engines will vary depending on such factors as engine manufacturer, operating condition, load, and fuel characteristics.

Table 4-13. Summary of Possible Impacts to Air Quality from Activities Related to Natural Gas Development

	Activity	
Program Phase	Reference Program	Onland Drilling Alternative
I. Exploration and development	Operation of rig power supply, service vessel, and tugs	Operation of rig power supply
	Well testing	Well testing
	Well stimulation	Well stimulation
	Failure of casings or blowout prevention equipment	Failure of casings or blowout prevention equipment
II. Production	Wellhead and pipeline maintenance	Wellhead and pipeline maintenance
	Gas production facility operation	Gas production facility operation
	Rupture of flowline	Rupture of flowline
	Wellhead failure	Wellhead failure
	Explosion and fire at the production facility	Explosion and fire at the production facility
III. Decommissioning	Removal of pipelines, well abandoment	Removal of pipelines, well abandonment

4.111
However, average per-engine emissions (representative of engines used for these operations and assuming 700 hp diesel engine with a fuel consumption rate of 21 gal/h) are as follows (USEPA 1977a):

Diesel Engine Emission Rates

	kg/h
Sulfur oxides	0.30
Carbon monoxide	0.95
Exhaust hydrocarbons	0.36
Nitrogen oxides	4.45
Aldehydes	0.07
Particulate matter	0.32

4.112
Service vessels and tugboats that tend and tow the drilling rigs are powered by engines similar to those supplying power to the drilling rigs. However, due to the intermittent operation, limited number, and areal coverage of these vessels, the air quality impact resulting from their operation is expected to be minimal.

4.113
The air quality impact of diesel engine emissions from jack-up and floating rigs is assessed by comparison of predicted surface-level contaminant concentrations to the most stringent federal and state air quality standards (Table 4-14). Air contaminant concentrations at the water surface are calculated by a standard straight-line steady-state Gaussian model using the emission rates given above. Maximum concentrations are predicted to occur at 1000 m from the rig. Comparison of the computed concentrations in Table 4-15 with the air quality standards given in Table 4-14 shows that pollutant concentrations are well within ambient standards. All predictions of ambient pollutant concentrations, where the assessment is supported by a quantitative analysis, are based upon equations from Turner (1970).

4.114
Gaseous emissions associated with well development are generated during well stimulation and drill stem test procedures. The gases released during these procedures consist of a combination of natural formation gas and stimulation gas. Gases from drill stem tests will be flared. Combustion products will consist of sulfur dioxide (Lockport Formation), hydrocarbons, and negligible particulates. Typically, nontoxic gases (e.g., carbon dioxide) are used for well fracturing. Only in the Lockport Formation, in which the formation gas contains an average of 1% hydrogen sulfide (H_2S), will stimulation result in the release of toxic gas. Total H_2S release for this situation is estimated to be a maximum of about 100 kg per well, over a period of 12 hours.

4.115
The toxicity of H_2S gas is comparable to cyanide and about five to six times greater than for carbon monoxide. An increased tolerance for H_2S is never acquired through increased exposure; instead, a hypersensitivity may result from exposure to the gas. Low concentrations have an irritant action on human

Table 4-14. Most Stringent Federal and State Ambient Air Quality Standards

Pollutant	Standard	Concentration ($\mu g/m^3$) Federal[a]	New York[b]	Pennsylvania[b]	Ohio[b]
Photochemical oxidants	1-hour standard, not to be exceeded more than once per year	240	240	240	240
Particulates	24-hour standard, not to be exceeded more than once per year	260	80	260	150
Sulfur oxides	24-hour standard, not to be exceeded more than once per year	365	260	365	260
Carbon monoxide	8-hour standard, not to be exceeded more than once per year	10,000	10,000	10,000	10,000
Hydrocarbons	3-hour (6-9 a.m.) standard, not to be exceeded more than once per year	160	160	160	126
Nitrogen oxides	Annual arithmetic mean[c]	100	100	100	100
Lead	Maximum quarterly average	1.5	1.5		1.5
	30-day standard, arithmetic mean of 30 consecutive 24-hour average concentrations			5	

[a]Source: 40 CFR 50.

[b]State air laws.

[c]Not directly applicable to short-term releases due to drilling operaton.

Table 4-15. Worst-Case Surface-Level Pollutant Concentrations at 1000 m from a Drilling Rig[a]

Pollutant	Concentration ($\mu g/m^3$) per Averaging Time: 3 hours	8 hours
Particulates	11	10
Sulfur oxides	10	9
Carbon monoxide	31	28
Hydrocarbons	12	11
Nitrogen oxides	148	136
Aldehydes	2	2

[a]Meteorological conditions: Class F stability and 1 m/s average wind speed for the entire period. Effective release height: 20 m.

respiratory passages, mucous membranes, and the eye's cornea. High concentrations have a systemic effect; with acute poisoning, death is rapid. Prolonged exposure to concentrations of 16 $\mu g/m^3$ are possible with no effect. The maximum concentrations that can be inhaled for one hour without serious effects range from about 270 to 470 $\mu g/m^3$. Slight symptoms are noted after exposure to concentrations in the range of 100 to 220 $\mu g/m^3$ for several hours (Archibald 1976).

4.116
Impact assessment of H_2S release from well stimulation in the Lockport Formation is made by comparison with existing threshold limit values (TLVs). The TLVs for the time weighted average (TWA) and the short-term exposure limit (STEL) for H_2S are 15 and 27 mg/m^3 respectively.* As is apparent from comparison of these limits with the predicted maximum concentrations in Table 4-16,

Table 4-16. Surface-Level Concentration of Hydrogen Sulfide Gas from Well Stimulation

Distance (m)	Concentration (mg/m^3) per Averaging Time			
	15 minutes[a]	1 hour[a]	3 hours[a]	8 hours[b]
100	83	62	51	8.3
250	14	10	9	1.9
500	4	4	3	0.6

[a]Meteorological conditions: Class F stability, 1 m/s wind speed. Surface-level release.

[b]Meteorological conditions: Class E stability, 2 m/s wind speed. Surface-level release.

the STEL can be exceeded at 100 m from the release point. It is expected that the crew will be working much closer to the stimulated well than 100 m, so that short-term concentrations in worker areas may exceed those given in the table and the STEL. The rig operator will be responsible for recognizing and adhering to safety requirements for drilling in a hydrogen sulfide environment, e.g., onboard deployment of H_2S detectors and oxygen masks, and for display of warning flags to alert passing vessels in case of an encounter with H_2S. These requirements should be at least as strict as those promulgated by the U.S. Geological Survey for operators working in Outer Continental Shelf waters of the United States, and appropriate elements should be incorporated into lease provisions.

*The time weighted average is the concentration for a normal 8-hour workday to which nearly all workers may be repeatedly exposed (day after day) without adverse effect. The short-term exposure limit (STEL) is the maximum concentration to which workers can be exposed continuously for a period of up to 15 minutes without suffering from irritation, chronic or irreversible tissue damage, or narcosis which would reduce work efficiency or impede self-rescue. The STEL should be considered a maximum allowable concentration, not to be exceeded at any time during the 15-minute excursion period (Elkins et al. 1979).

4.117
During the production phase of the program, wellheads and pipelines will be routinely cleaned and maintained. This procedure will require that wells be closed, and lines opened, cleaned, and bled to atmospheric pressure. The volume of gas released during this operation will be determined by the check-valve system in the pipeline. The release point may be onshore or underwater.

4.118
The magnitude of air emissions from the operation of onshore gas production plants will depend on the volume of gas processed, composition of the raw gas, plant design, and pollution control equipment installed. Sources of air emissions at gas plants include processing equipment, evaporation leakage, and combustion from machinery. In the Reference Program and Onland Alternative Program, it is assumed that all operators will obtain necessary local, state, and federal air quality permits prior to construction and operation of production facilities.

4.119
Processing facilities that receive raw gas from the Clinton-Medina formations will consist only of a compressor and a gas dehydration unit (see Appendix B, Table B.6). The raw gas will be compressed using natural-gas-fired reciprocating engines. Glycol reboilers used in gas dehydrators will be external combustion boilers also fired by natural gas. Total emission rates for compressors are given in Table 4-17. The size and output from these compressors will dictate whether a Prevention of Significant Deterioration (PSD) permit will be required and whether operational ambient monitoring will be required in the vicinity of the facility. At the present time, Ohio has received PSD primacy whereas Pennsylvania and New York have not.

4.120
Gas treatment facilities that receive raw gas from the Lockport Formation will require H_2S removal and recovery capability in addition to compressors and dehydrators (see Appendix B, Table B.7). Only the onshore facilities receiving

Table 4-17. Gaseous Emissions from Reference Program Compressors at Landfalls 1 Through 7 and 9[a]

	Gaseous Emissions (kg/h) per Landfall							
Pollutant	1	2	3	4	5	6	7	9
Nitrogen oxides (as NO_2)	3.90	4.67	7.69	5.35	8.12	7.03	11.22	11.17
Carbon monoxide	0.49	0.60	0.98	0.69	1.05	0.90	1.43	1.42
Hydrocarbons[b] (as C)	1.55	1.87	3.10	2.10	3.21	2.21	4.49	4.47
Sulfur dioxide	--	--	--	--	--	--	--	--

[a]Data from USEPA (1977a). Values represent compressor emissions only; glycol reboiler emissions will be negligible. Emissions correspond to compressor requirements for year with highest production.

[b]Total hydrocarbons; nonmethane hydrocarbons are estimated, on the average, to comprise 5 to 10% of this total.

sour gas from Lease Areas 13 and 14 will require such facilities. As described in Table 1-24, flowlines from these two lease areas are brought to shore at Landfalls 8 and 10 (see also Figure 1-1, map pocket). The sulfur recovery process will utilize the Claus process with sulfur dioxide conversion units to recover up to 99% of the total sulfur. Fugitive emissions of H_2S will be minimized by control valves or vessel drainage points. Vapors collected at these points will be reprocessed through the sulfur recovery facility. Evaporative losses of hydrocarbons can also be expected during gas compression and dehydration. These emissions occur at leakage points (e.g., valves) and increase proportionately with the amount of gas processed. Cavanaugh et al. (1976) estimated that about 0.44% of the total gas processed escapes as fugitive emissions. Currently available technology and rigorous maintenance schedules minimize such emissions. External combustion boilers for process heating and regeneration of chemical solutions will be fired by natural gas. Natural-gas-fired reciprocating engines will compress the gas. Emissions from gas facilities at Landfalls 8 and 10 are given in Table 4-18. Total emissions from these facilities will dictate whether a PSD permit will be required and whether operational ambient monitoring will be required in the vicinity of the facility.

Table 4-18. Gaseous Emissions from Reference Program Treatment Plant Compressors and Hydrogen Sulfide (H_2S) Removal and Recovery Units at Landfalls 8 and 10[a]

	Gaseous Emissions (kg/h)					
	Landfall 8			Landfall 10		
Pollutant	Compressor	H_2S Equipment	Total	Compressor	H_2S Equipment	Total
Nitrogen oxides	26.14	1.45	27.59	46.50	2.29	48.79
Carbon monoxides	3.3[illegible]	0.11	3.44	5.91	0.17	6.08
Hydrocarbons (as CH_4)	10.45	0.02	10.47	18.59	0.03	18.62
Sulfur dioxide	--	0.78	0.78	--	1.37	1.37

[a]Data from USEPA (1977a). Includes emissions from compressors and all emission sources from H_2S removal and recovery equipment. Emissions correspond to compressor and sour gas treatment requirements for year with highest production.

4.121
The impact on local air quality from compressor operation is assessed for the shore process facility with the highest emission rate located at Landfall 7. The assessment incorporates conservative meteorological conditions* for the

*Meteorological conditions yielding maximum short-term ground-level concentrations for compressor gaseous emissions consist of the combination of Class F stability and 1 m/s wind speed. These conditions are assumed to persist for a full 8 hours.

calculation of contaminant concentrations downwind of the facility. Resultant concentrations are given in Table 4-19. Short-term concentrations were computed at only 1000 m because based on an effective release height of 20 m and under very stable meteorological conditions, that is the distance to maximum impact. Annual average concentrations for nitrogen dioxide were calculated for shorter distances under a different set of conservative meteorological circumstances.* The air quality impact from compressor emissions at the other facilities will be proportionately less.

Table 4-19. Predicted Worst-Case Contaminant Concentrations in the Vicinity of Selected Reference Program Process and Treatment Plants

	Short-Term Concentrations ($\mu g/m^3$) at 1000 m								
	Landfall 7[a]			Landfall 8[b]			Landfall 10[b]		
Time	CO	HC	SO_2	CO	HC	SO_2	CO	HC	SO_2
1-hour	60	188	-	144	436	32	254	776	57
3-hour	48	150	-	115	349	25	203	620	46
8-hour	44	138	-	106	320	23	186	569	42

	Average Annual NO_2 Concentrations ($\mu g/m^3$)		
Distance	Landfall 7	Landfall 8	Landfall 10
500 m	66	162	286
750 m	27	67	119
1000 m	15	38	66

[a]Emissions from the compressor at Landfall 7 are greater than for all other gas process facilities.

[b]Emissions are from compressors and gas "sweetening" equipment.

Abbreviations: CO = carbon monoxide; HC = hydrocarbons; SO_2 = sulfur dioxide.

4.122

The air quality impact from treatment facilities at Landfalls 8 and 10 is assessed under the same conservative meteorological conditions which were used to assess process facility impacts. Predicted maximum contaminant concentrations are given in Table 4-19 for various average times and distances in the vicinities of processing and treatment stations at these landfalls. The predicted levels of HC and NO_2 in the vicinity of treatment plants at these

*Meteorological conditions assumed for the calculation of the annual average relative dispersion coefficient are as follows: 50% Class D with a 4 m/s wind; 30% Class E with a 3 m/s wind; 10% Class F with a 2 m/s wind; and 10% Class F with a 1 m/s wind. A maximum frequency of occurrence of 20% for wind direction into a given 22.5 degree sector is also assumed.

landfalls exceed applicable National Ambient Air Quality Standards (NAAQS). Both of these pollutants are precursors to the formation of ozone which is already at high levels in the region.

4.123
The magnitude of air emissions from routine operation of storage/staging facilities will depend on the volume of delivered, stored, and transferred fuel, supplies, and wastes associated with offshore gas operations. Emission sources include evaporation from fuel storage and transfer, combustion from machinery and vehicles, and accidental spills and breaks (New Engl. River Basins Comm. 1976). Local air quality impacts will depend on the size of the facility and the level of activity at a base, as well as site-specific characteristics of the environment.

4.124
The combined impacts from any new stationary emission sources and existing emissions must be evaluated when site-specific engineering information is available during the permit application process. Representative (nearby) onland, quality-assured monitoring data must be provided to assess the air quality status in the area. A USEPA Region V air quality analysis checklist could be provided to applicants for guidance as to the type and extent of air quality analysis generally required for new sources.

4.125
The release of a small amount of formation gas from the well, when the wellhead and tubing are removed, constitutes the only gaseous releases associated with the decommissioning program.

4.126
Localized air quality impacts associated with onshore construction activities (see Table 1-34) result from construction equipment exhaust emissions, open burning emissions, and fugitive emissions from construction of pipeline corridors, headquarters, and production facilities and/or other facilities. However, due to the limited areal requirement for land clearing and attendant restriction on equipment usage, it is anticipated that construction impacts on local air quality will be minor and transitory.

4.127
Gaseous releases, in decreasing relative frequency of occurrence, for accidents during the exploration and development phases of the Reference Program are as follows: encounter of a high pressure gas pocket releasing 3.7 MCFD gas for two days; rupture of a stimulation return line releasing 475 MCF gas over a period of 12 hours; gas kick with blowout conducted up the wellbore releasing 950 MCFD gas for 15 days; gas kick with blowout around the casing releasing 950 MCFD gas for 15 days; and an oil blowout conducted up the wellbore releasing 300 MCFD gas for 15 days (see Table 1-35).

4.128
Production phase accidents with potential gaseous releases are rupture of an 8-inch gas flowline, releasing 23.75 MMCFD gas for three days; breaking-off of a wellhead releasing 475 MCF over a 12-hour period; and explosion and fire at a gas processing or treatment plant releasing combustion products from 23.75 MMCFD gas for one day.

4.129
Accidental gaseous releases from an explosion and fire at a gas treatment plant or from the rupture of an 8-inch gas flowline can have a potentially deleterious effect on the general public. Combustion products resulting from an explosion and fire at a treatment plant include sulfur oxides, particulates, and hydrocarbons. Although the specific impact of this event on residents in the plant vicinity cannot be quantitatively assessed, it is expected that these residents would need to be evacuated. The rupture of a natural gas flowline, either onland or underwater, could result in the buildup of combustible gases and an explosion if an ignition source is nearby (McGregor et al. 1978). For example, a ruptured 8-inch gas flowline could bubble gas to the Lake surface and, under worst-case dispersion assumptions, result in a potentially explosive cloud extending as far as 700 m from the point of release to the atmosphere, with a maximum width of less than 15 m. The area peripheral to this potentially explosive cloud would have to be identified and restricted from use by all boaters. The same event could occur with the rupture of onland gas flowlines, and nearby residents would have to be evacuated. The rupture of an 8-inch flowline carrying H_2S gas would require the evacuation of all people within 500 m of the break to avoid the toxic effects of the gas. A larger area would probably be voluntarily evacuated by anyone in the area to avoid the annoying smell of the H_2S gas. Affected areas would need to remain evacuated until the release of gases from the leak could be stopped and until the potentially explosive and/or toxic gases had a chance to disperse.

Impacts of the Onland Alternative Program

4.130
With respect to air quality impacts, the major difference between the Reference Program and the Onland Alternative Program is the relatively larger amount of particulates generated during construction, well development, and decommissioning phases of the Onland Alternative Program. The actual rate of generation for the fugitive particulates is dependent on the specific activity, soil type, weather conditions, amount of disturbed land, and dust mitigation procedures. The amount of land disturbed will average about 3 acres per well site, with pipeline rights-of-way requiring only 10 to 30 ft of clearance. Fugitive dust mitigation procedures, consisting of watering the disturbed area and determined by local soil and weather conditions, can be applied during construction.

4.131
Particulate and gaseous emissions generated during well development begin with access/service road construction, site preparation, and the initial movement of drilling equipment onsite. Emissions associated with the site preparation and equipment rig-up are characterized as fugitive dust and combustion emissions from construction equipment. Drill stem tests and well stimulation also result in gaseous emissions. Drill stem test gases will be flared, yielding incomplete combustion products, sulfur dioxide, and hydrocarbons. In comparison to particulate and gaseous emissions generated during these phases of the Reference Program, only particulate emissions are significantly greater.

4.132
The rig power supply consists of an internal combustion diesel engine consuming fuel at about the same rate as the drilling rig in the Reference Program. Therefore, the emission rates are representative for the engines used here.

The air quality impact of drill rig, process facility, and treatment facility operation will be similar to that predicted for analogous activities for the Reference Program. Worst-case ambient concentrations for offshore drilling rig emissions, given in Table 4-15, are also applicable for onland drilling rigs. Worst-case predictions of ambient concentrations of process and treatment facilities (Table 4-19) are representative for stations processing similar amounts of gas obtained from onland wells.

4.133
Particulate and gaseous emissions associated with the production phase of the Onland Alternative Program result primarily from routine well maintenance and production facility operation. Emissions from wellhead maintenance consist of natural formation gases. Production facility pollutants are identical to those given in Table 4-17 and 4-18 for the Reference Program. The emission rates are proportional to the amount of gas processed.

4.134
The decommissioning program will result primarily in particulates generated from the return of drilling sites to their original condition and the removal of necessary pipelines. Also, gaseous and particulate emissions will result from the operation of construction equipment.

4.135
The magnitude of gaseous releases from Onland Alternative Program accidents are assumed to be identical to releases associated with Reference Program accidents.

4.136
Accidental gaseous releases associated with the Onland Alternative Program have a potential for more severe impact than counterpart releases of the Reference Program due primarily to the closeness of nearby residents. The only accidents with potential deleterious effects on the general public are the rupture of a 8-inch gas flowline and an explosion and fire at a gas production/treatment facility. The discussion of these accidents under Reference Program assumptions is also applicable to the Onland Alternative Program.

ESTHETIC IMPACTS

Impact Sources

4.137
The perception of esthetic or scenic resource values involves behavioral as well as physical interpretation. Characteristics of the stimulus being observed, characteristics of the stimulus observer, and the context in which the stimulus is being observed are three generally accepted factors influencing the esthetic response (Pitt 1978). The stimuli observed during Reference Program activities will include all visible man-made structures or visually perceivable changes in water quality. Impacts to the stimulus observer are relative to the setting and to the type of activity the observer is engaged in.

4.138
The five prototype settings discussed in Chapter Three represent the broad spectrum of esthetic values that may be experienced within the Reference

Program Study Region. Each setting, which is an aggregate representation of the vast number of existing site-specific possibilities, is evaluated here for general type and magnitude of impact. In this evaluation, only general principles and worst-case situations can be judged relative to natural gas development impacts within the prototype settings. A methodology could be developed to determine and evaluate site-specific esthetic characteristics in the event that the Reference Program is approved.

4.139
There exists a consistent relationship between perceived scenic value and the visual pattern created by various spaces, colors, forms, and textures comprising a landscape. Physical structures and their specific influence on existing visual patterns will depend on site-specific characteristics of the locations.

4.140
Those physical structures that change existing patterns of space, color, form, and texture, thereby altering the visual field, are impact sources. These alterations may or may not create a negative impact. Physical structures or possible fluid discharges associated with the Reference Program which could potentially impact the esthetic quality of the existing environmental settings are listed in association with the types of setting in which they would most likely occur, as well as the expected degree of impact in worst-case situations (Table 4-20).

Table 4-20. Summary of Possible Sources and Magnitudes of Impacts to the Esthetic Environment from Reference Program Activities

Prototype Setting	Impact Sources	Degree of Impact (worst-case situations)
1. Urban/Industrial	Gas processing and/or treatment plants	Minor
	Pipeline corridors	Minor
	Service vessels	Positive
2. Residential	Gas processing and/or treatment plants	Moderate
	Pipeline corridors	High
	Jack-up and floating rigs	Negligible
	Service vessels	Positive
3. Open Water	Jack-up and floating rigs	Moderate
	Service vessels	Positive
	Fluid discharge and leakage	Minor
4. Multi-Use Recreational Beach	Gas processing and/or treatment plants	Moderate
	Pipeline corridors	High
	Jack-up and floating rigs	Negligible
	Service vessels	Positive
5. Natural	Gas processing and/or treatment plants	High
	Pipeline corridors	High

Impacts of the Reference Program

Prototype Setting No. 1: Urban/Industrial

4.141
More than 23% of the lands bordering the lakeshore are devoted to industrial, commercial, or public facilities and associated activities (Gr. Lakes Basin Comm. 1975d). User groups within these settings are generally not anticipating views possessing particularly good quality. On this assumption alone, the effects of Reference Program structures introduced into this type of setting will not create a negative impact. The addition of service vessels, drilling rigs, tugs, and barges may add a unique temporary attraction to the existing man-influenced character of the setting and consequently enhance its visual appeal (see Figure 4-1). Onland Reference Program structures may also be

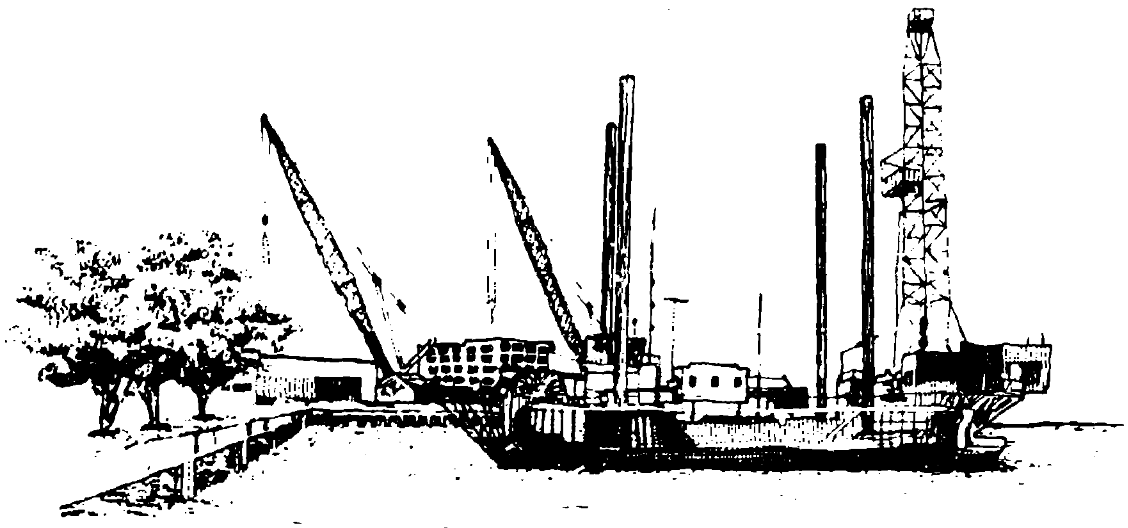

Figure 4-1. Urban/Industrial Setting Altered by the Addition of a Reference Program Drilling Rig.

integrated into the settings' existing nearshore development, avoiding undue disruption of esthetic quality. Viewsheds within urban/industrial settings contain strong linear forms (e.g., jetties, piers, buildings) whose impacts to the natural environment have already been established, thus providing a compatible setting into which harbor facilities, pipeline corridors, and gas production facilities could be introduced.

4.142
In general, urban/industrial settings that contain buildings and other structures serve as the best prototypical situations into which Reference Program structures can be adapted.

Prototype Setting No. 2: Residential

4.143
The user groups in residential settings are extremely critical of viewshed quality to and from the shoreline. Precautionary measures designed into the Reference Program that will reduce esthetic impacts in residential settings include a one-mile buffer zone from the shoreline in which drilling is excluded, a setback requirement away from the immediate nearshore area for onland processing and treatment facilities, underwater wellheads and pipelines, nonpermanent drilling platforms, subsurface pipeline protection structures at landfalls, and construction of pipeline corridors nonperpendicular to the shore edge.

4.144
The erection of Reference Program processing and/or treatment plant buildings, roads, and parking areas will not give rise to greater impact than that caused by the routine siting of small, residential or commercial buildings (Figure 4-2). Proper facility location and treatment of architectural style, color, and vegetation can render these impacts negligible.

4.145
Assuming no other existing facilities are available for conversion and use, a total of approximately 3 to 10 acres of undeveloped land would be altered within 0.5 mile inland from each of the 10 Reference Program pipeline landfalls. The visual pattern created by characteristics of the stimulus being observed (e.g., the strong linear form of pipelines and corridors) can

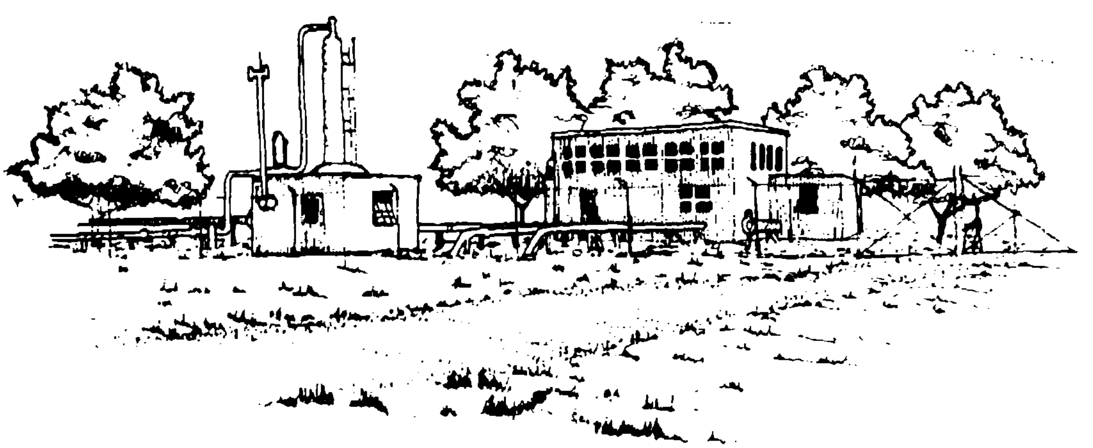

Figure 4-2. Unbuffered View of a Reference Program Gas Production Facility in an Undeveloped Residential Setting.

negatively impact the esthetic quality of any prototype setting if not properly designed. According to aerial photographic analysis of existing pipeline corridor clearings (Consumer's Power Co. 1978), the corridor width of a 16-inch pipeline can vary from 22 to 30 ft. Maintenance of a low grass forb cover throughout the pipeline corridor will usually alter the esthetic nature of the residential setting. In most cases, the degree of impact will increase as the amount of vegetation altered or removed increases. The most significant visual impacts of pipeline corridor development (in any setting) will result from soil exposure, which creates a striking contrast to the surrounding settings in line, color, and texture. Scars will heal in a relatively short time depending on revegetative capabilities. Perceived contrast can be expected to increase as the corridor angle increases towards the viewer, such as on sloped topography or over a bluff edge. Roads (and adjacent buffer edges) connecting residential areas can offer convenient space to accommodate the addition of pipeline corridors, thus eliminating the need to clear extra corridor space. Areas of existing low grass forb cover--such as agricultural fields, and highway, railroad, or utility easements--will sustain less impact from corridor development than will forest landscapes with pipeline paths cleared in a swath (Figure 4-3).

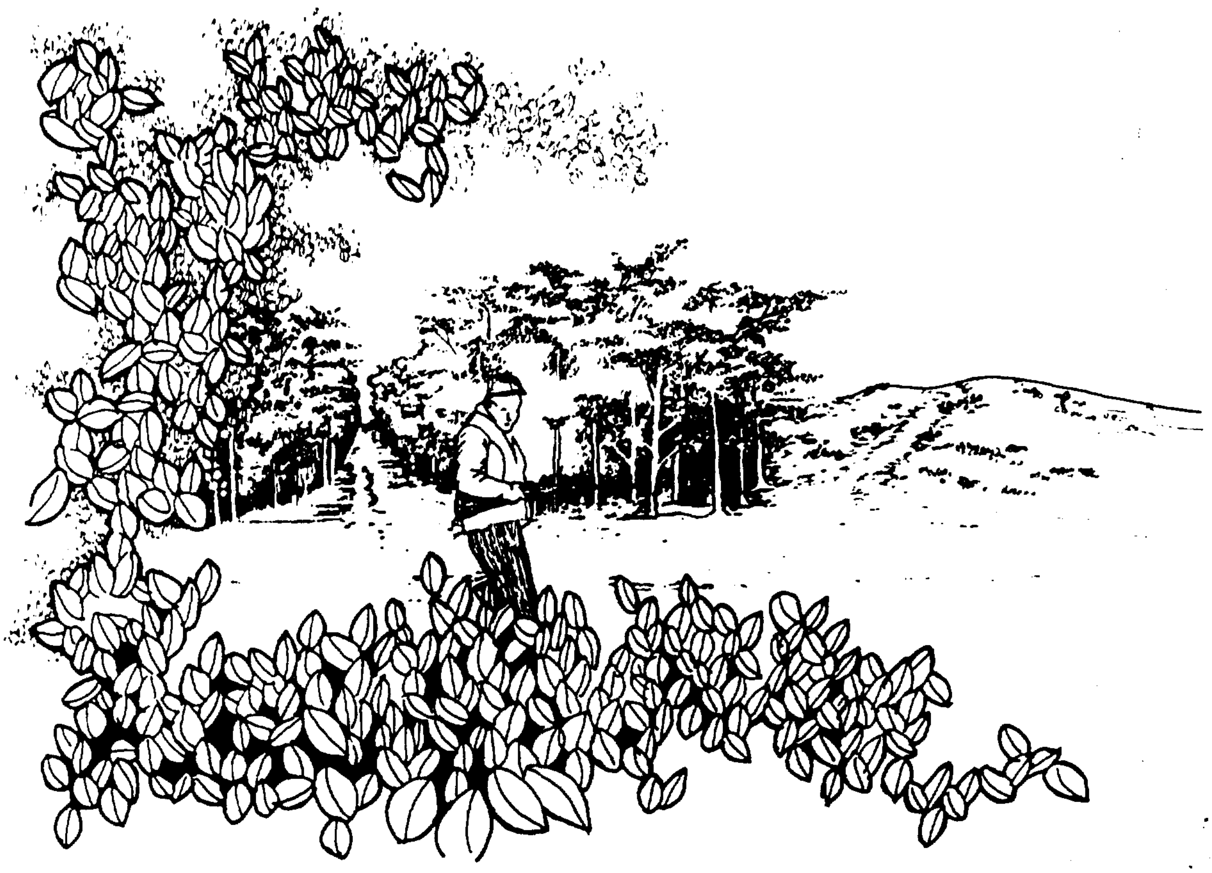

Figure 4-3. Views of a Pipeline Corridor Through Two Different Vegetation Densities. This illustration deviates from Reference Program assumptions since two corridors will never be located adjacent to one another.

4.146
Views of jack-up and floating rigs are, at worst, a minor source of potential impact to the residential user group (Figure 4-4). The addition of vertical elements (jack-up and floating rigs), contrasting with the uninterrupted horizon line, could be compatible with or degrade surrounding viewsheds depending on the observer's point of view. Because of the one-mile depth of field (defined by the buffer zone), the ~ 125-ft sections of rig mast and platform or vessel will appear diminished in height to the viewer. Additionally, because of their mobility and nonpermanence, vessels moving on the Lake are often considered interesting (as opposed to a permanent encroachment) and may enhance visual quality.

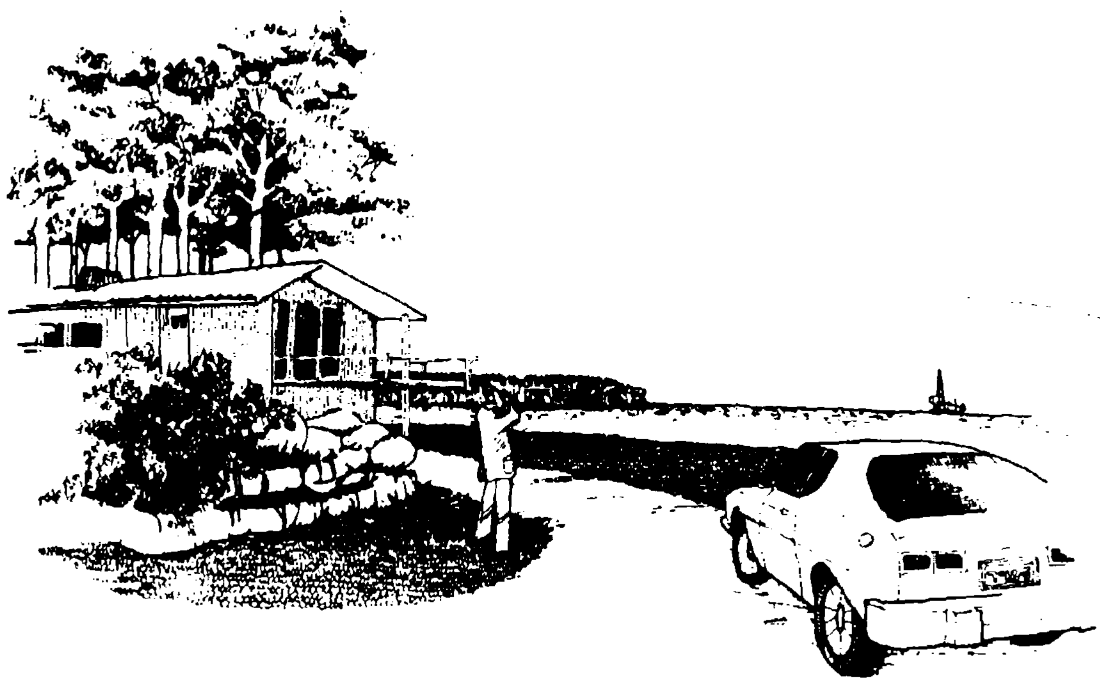

Figure 4-4. Drilling Rig Sited at the Fringe of a One-Mile Buffer Zone as Viewed from a Residential Setting.

4.147
Disruptions of the visual field by introduction of rigs drilling on location (close to the one-mile buffer edge) will occur for a maximum of only 10 days. The effects of a one-mile visual buffer zone, combined with the transient nature of the gas drilling process, should produce negligible esthetic impacts from open water Reference Program drilling activities viewed from any setting (Figure 4-5).

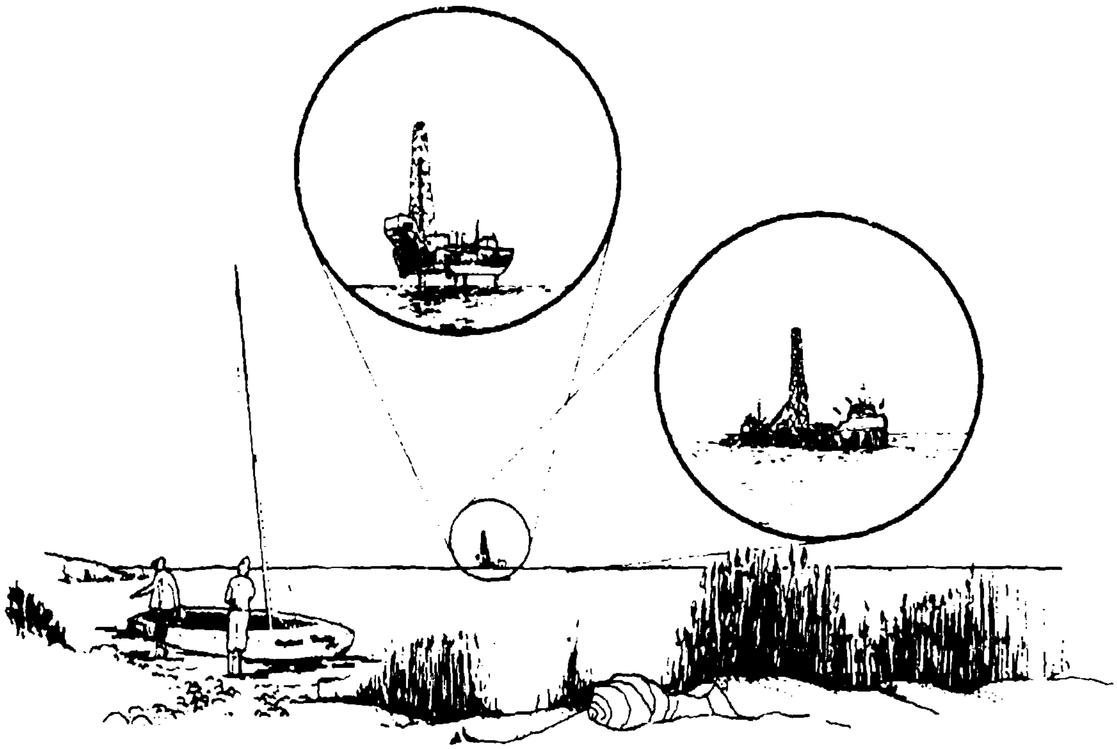

Figure 4-5. Reference Program Drilling Rig (Jack-up or Floating) Sited at the Fringe of a One-Mile Buffer Zone as Viewed from a Natural Area Setting.

Prototype Setting No. 3: Open Water

4.148
In the open water, worst-case situations will occur infrequently when boaters venture far enough from shore to be within sight of jack-up or floating rigs during the 5- to 10-day drilling period. Boaters perceiving a negative impact would most likely be seeking solitude on a horizon void of man-made structures. In a different sense, vertical obtrusions can be considered unique and interesting focal points in the barren seascape (Figure 4-6).

4.149
Impacts to the esthetic water quality caused by the minor routine release of fluids during stimulation and decommissioning, as well as the infrequent occurrence of accidental fluid release, are potential sources of impact in the open water setting. In general, impacts to esthetic water quality should be minimal due to the localized, temporary, and infrequent nature of planned releases and the potential for prompt attention to an identified spill by the appropriate accident-response agency. User perception of such impacts will not occur unless boaters are floating on or adjacent to water containing the dispersed fluids near the point source of impact.

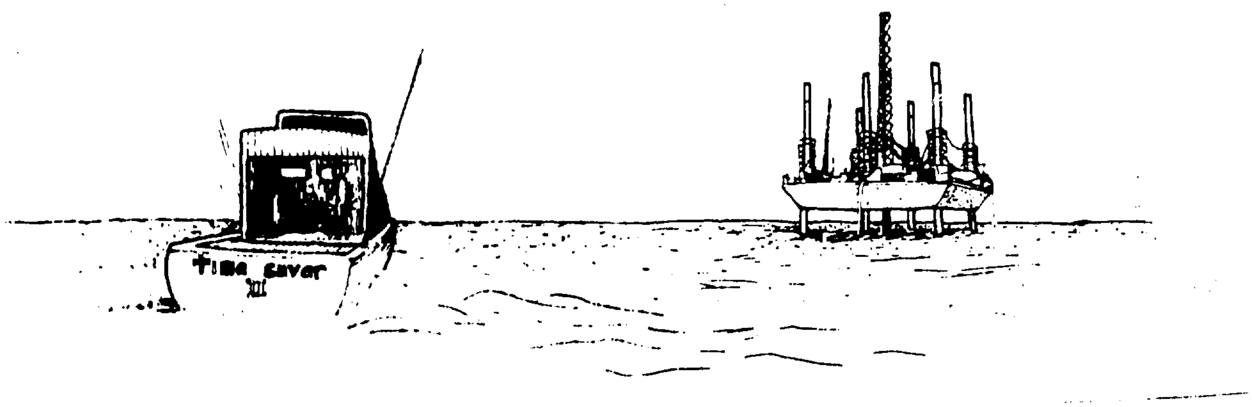

Figure 4-6. View from the Open Water Setting Altered by an Encounter of a Recreational Boater with a Jack-up Drilling Rig.

Prototype Setting No. 4: Multi-Use Recreation

4.150
Impacts of Reference Program activities on the multi-use recreation setting will depend on siting techniques and seasonal timing. If pipeline corridor construction and decommissioning procedures are performed during the off-season (winter months), impacts to this setting will be negligible. The impacts of corridor design and offshore views are similar to those discussed relative to the residential prototype setting. Visual impact evaluation of temporary offshore equipment discussed relative to residential settings also applies to the multi-use recreational setting. Intrusive impacts are further reduced by the user groups' participation in more active and distracting activities, such as swimming and boating (Figure 4-7).

Prototype Setting No. 5: Natural Areas

4.151
The most influential factor affecting the esthetic quality of the natural area setting is the construction and maintenance of pipeline corridors and gas production facilities. Coastal Zone Management programs of Ohio, Pennsylvania, and New York are highly protective of critical wetlands and will most likely prohibit siting of any landfalls, pipelines, or onland facilities in these areas. Natural areas not explicitly restricted from development by law are potential Reference Program development sites and are generally most susceptible to esthetic degradation. An intrusion of man-made structures within unprotected natural settings will most likely impact natural character, thus influencing the perceptions of this setting's user groups.

4.152
The siting considerations discussed for pipeline corridors and gas production facilities in urban/industrial and residential settings also apply to natural area settings. The degree of impact in unprotected natural areas will depend

Figure 4-7. Drilling Rig Sited at the Fringe of a One-Mile Buffer Zone as Viewed by Active Participants in a Multi-Use Recreation Setting.

on vegetation type and density. An unnatural clearing created in a dense stand of vegetation is more noticeable than one established in sparse growth (Figure 4-8). Location of facilities in these settings should result only from absolute necessity.

Impacts of the Onland Alternative Program

4.153
Esthetic impacts associated with onshore drilling activities would be similar to those discussed regarding intrusions of the land-related elements employed in the Reference Program. Much greater impact could result from the Onland Alternative Program relative to the amount of landform and vegetation alteration required for pipeline corridors leading from wellheads to gas production facilities. The corridors for feeder lines, trunk lines, gathering lines, and flowlines would necessitate a certain degree of landscape alteration, depending on site-specific factors. Wellhead dewatering and metering equipment would remain a semipermanent intrusion to the visual field for each producing well (Figure 4-9).

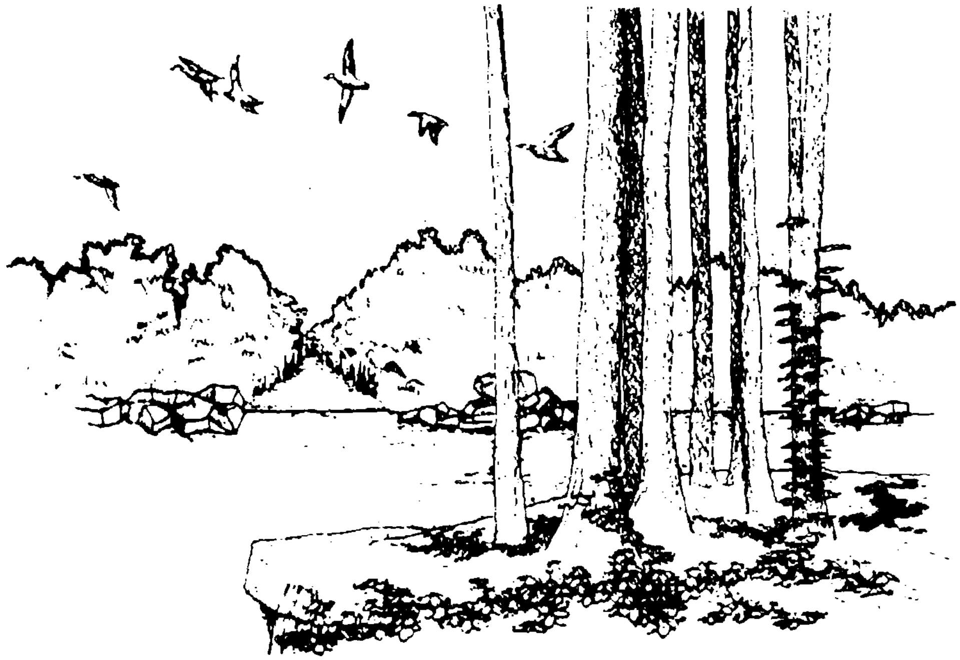

Figure 4-8. View of a Pipeline Corridor Introduced into a Densely Wooded Natural Area Setting

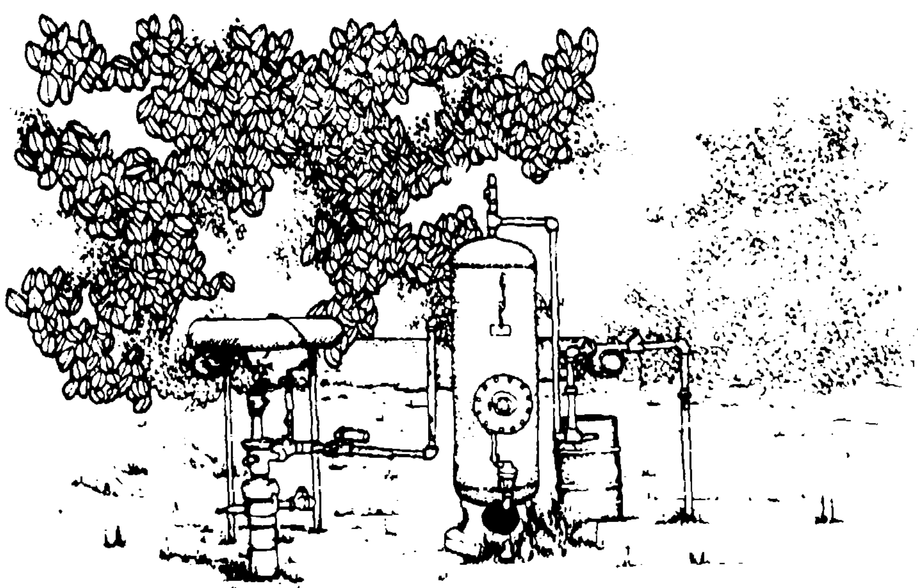

Figure 4-9. View of Onland Alternative Program Wellhead and Dewatering Equipment Located Adjacent to the Lake.

CULTURAL RESOURCES

4.154
Sources of direct impacts to cultural resources that may be present in both the Reference Program Study Region and the Onshore Alternative Study Region will result from activities that disturb the current ground surface or subsurface. All phases of a development project including site preparation, drilling, construction, operational maintenance, accidents, and decommissioning are associated with activities that affect the present ground surface and subsurface, including landforms submerged beneath Lake Erie.

4.155
Sources of indirect impacts to cultrual resources may result from the local residents and project personnel who collect, excavate, or otherwise disturb cultural resource objects and sites. In addition, erosion, alluviation, etc., can occur as an indirect consequence of land-use changes associated with the direct impacts discussed above.

4.156
Specific impacts of natural gas development in the Reference Program Study Region are being determined as part of a multi-faceted cultural resource study of Lake Erie and a one-mile area inland from the lakeshore. Currently, secondary prehistoric and historic data are being collected and analyzed. When this phase of the project is completed, a predictive model will be constructed to identify the different potentials of select lease areas for containing cultural resources of various kinds and densities. At that time, it will be possible to make more realistic appraisals of the potential impacts at site-specific locations if gas development were to take place. Guidelines will be developed for conducting cultural resource inventories, for performing cultural resource evaluations, and for developing programs to mitigate potential cultural resource impacts.

SOCIOECONOMICS

Employment

Impact Sources

4.157
The social infrastructure of the Reference Program Study Region could be affected in numerous ways by both offshore and onland gas development. Significant population growth or decline caused by employment opportunities in a particular area could have an impact upon the housing supply, school system, medical facilities, water supply, sewage treatment, solid waste disposal, police and fire protection, and other necessary public goods and services. Thus, anticipated employment requirements and consequential population changes were examined to determine the requirements for community services and facilities.

4.158
Direct employment refers to those workers employed by the three operators (assumed) who would be directly involved in the lake development activities (both onshore and offshore). Direct employment will be at its highest level during the development phase of the Reference Program. Later, when gas production becomes the primary activity, the number of employees will decline. Estimates of total direct employment have been based on considerations of each phase of the Reference Program. Types of employment are described by program phase for construction and routine operation of each facility. This information has been based on prior offshore development experience wherever possible.

4.159
Since a seismic survey has already been completed, the first stage discussed is the exploratory drilling.

4.160
Approximately 40 people will be required to man each Reference Program drilling rig (see Table 4-21 and Table B.2 [Appendix B]). Exploratory rig employees typically follow the rig from job to job and often reside near the rig's home port (Zinn 1978).

4.161
Temporary headquarters and staging and storage facilities will support the exploratory operations. An additional five employees per rig will be needed for shore-based exploratory support activities centered around these shore facilities.

4.162
Developmental drilling will require the same number of employees per rig as will be needed for each exploratory drill rig. Onshore support staff for shoreside management and material transfer will increase to 10 employees per rig during development activities. Well stimulation will require fewer workers (approximately eight per operator, see Table 4-21 and Table B.4 [Appendix B]) than required during drilling; workers would have many similar characteristics of the exploratory and production employees (Zinn 1978).

4.163
Onshore gas production facilities would require few people for operation and maintenance (see Table 4-21, and Tables B.6 and B.7 [Appendix B]). Process facilities are generally unmanned, with only daily inspections by one or two operator employees. Periodic machinery maintenance requires two operator mechanics. Gas treatment facilities would be continuously manned by 5-10 employees. Estimates of direct employment for the exploratory, development, and production phases are presented in Table 4-21.

4.164
Other jobs will be created by Reference Programs activities. Indirect employment, or jobs in support services which are contracted directly, will occur. Many of these services will be on a one-time basis--e.g., pipeline, facility, and building construction--whereas others may last as long as the program, e.g., handling of materials at harbors and maintenance of rigs. The number of indirect jobs that may be associated with the Reference Program are found in Table 4-21.

Table 4-21. Estimated Annual Number of Employees During Each Phase of the Reference Program

Program Phase	Direct Employment	Indirect Employment[a]	Induced Employment[b]	Total Employment	Local Hires	In-Migrants	In-Migrants × No. of Rigs
Exploratory Drilling							
Rig employees[c]	40	20	120	180	120	60	180[d]
Onshore staff people per rig	5	5	20	30	25	5	15[d]
Total	45	25	140	210	145	65	195
Development							
Rig employees[c]	40	20	120	180	120	60	480[e]
Onshore staff people per rig	10	8	36	54	44	10	80[e]
Stimulation barge employees	8	4	24	36	24	12	36[f]
Total	58	32	180	270	188	82	596
Production (per operator)							
Pipeline construction workers	2	25	54	81	70	11	33[g]
Onshore staff	15	10	50	75	60	15	45[g]
Production facility employees	10	5	30	45	40	5	15[g]
Total	27	40	134	201	170	31	93

[a]Indirect employees hired on a one-time basis will be averaged yearly over the lifetime of the phase (e.g., exploratory, 1 year; development, 20 years; production, 20 years).

[b]Induced employment has been estimated by applying a multiplier of 2.0 to the total of direct and indirect employment.

[c]Includes service vessel.

[d]Assumes 3 exploratory rigs and service vessels.

[e]Assumes 8 drilling rigs and 3 service vessels.

[f]Assumes 1 stimulation barge for each of the three operators.

[g]Total of new employees for all three operators.

4.165
Permanent harbor facilities will be required during developmental activities. Either new buildings will be constructed or existing structures will be modified to meet program needs. A small local work force of approximately 25 skilled and unskilled employees will be required for each construction or modification project. Construction of pipelines and landfalls will probably be contracted to a local company(s). Pipeline workers tend to migrate from job to job. Approximately 25 welders, pipefitters, divers, and barge operators would be required by each operator to construct underwater pipelines, landfalls, and onshore pipelines. Specialized workers, such as welders and divers, may not be available locally; thus, new workers may be attracted to the region. Handling, transport, and disposal of wastes from gas production facilities would be contracted to local waste management firms.

4.166
Finally, new jobs are generated when direct and indirect employees spend money in the region and operators purchase goods. This induced employment will occur in both the public and private sectors (e.g., doctors, firemen, store clerks). The number of estimated induced jobs is presented in Table 4-21.

4.167
Industry operators will decide to develop new areas and build new facilities based upon the following information; the extent of the gas "find", distance from established company bases, available labor supply, and transportation costs (Zinn 1978). Since the location and extent of offshore gas reservoirs is uncertain, the task of defining areas of social and economic impacts becomes complicated. Also, extensive development of a particular area could significantly affect the social and economic equilibrium of the area. Thus, two factors--the amount of development and the specific location--govern the scope and severity of socioeconomic impacts. Another factor influencing the type of impact expected involves the number and skills of local workers.

4.168
In the absence of specific information on the location of onland development, the discussion of Reference Program employment effects can be applied in a general way to the Onland Alternative Program.

Impacts of the Reference Program

4.169
Within this section, the social impacts due to changes in population resulting from the Reference Program will be examined on both a regional and local level. This section also contains a discussion of the cumulative impacts of offshore gas development and associated onshore activities upon the Reference Program Study Region.

4.170
In the Reference Program, maximum drilling activity involving all three states will occur from 1985 to 1988. After this time period, first New York and then Pennsylvania will experience a decrease in drilling activity paralleled by a corresponding increase in drilling activity in Ohio.

4.171
The year 1985 has been identified as the year in which the effects of peak employment are assessed. During that year, all eight rigs will be in operation, and the three states will be witnessing both the developmental and production phases of the program. Table 4-22 summarizes projected peak employment including the number of in-migrants. Drilling and production activities will generate approximately 6300 jobs in the region. Since most people will be hired from the local labor pool (approximately 80%), less than 1300 employees will move to the area for employment in the program.

4.172
No impact to the region will be caused by these in-migrants. Even assuming that all the in-migrants had partners and two children, the total number of new residents is much less than 0.5% of the total population of the region (see Table 3-10). The area is expecting a population increase of over 300,000 people during 1980 and 1990, and the influx of approximately 3500 to the area (or about 1% of the area's projected growth) caused by the drilling program will be unnoticed. The region has begun preparations for a growth in the demands upon its services and resources (e.g., housing, schools, sewage treatment facilities) for the coming decade, and the area can provide whatever goods and services that may be required by the new movers.

4.173
Buffalo and Erie will be the major ports for drilling and production activities in New York and Pennsylvania. Peak years of employment affecting these two cities is expected to be between 1985 to 1988 for Buffalo and 1983 to 1991 for Erie, with 1985 as the standard peak year. As seen in Table 4-22, about 250 people are projected to move to Buffalo for employment according to Reference Program assumptions. Erie County, New York, currently has over a million people. The projected population increase from the Reference Program in-migrants will be indiscernible. The population of Erie County in Pennsylvania is much smaller, but the estimated 980 in-migrants (employees plus families) will still be less than 1% of the county's projected 1980 population.

4.174
Maximum drilling activity will occur in Ohio during 1992 to 1995 when seven rigs will be drilling in five lease areas. The peak employment demands for 1995, assuming seven drilling rigs and full production employment, are presented in Table 4-23. The approximately 1700 movers (employees and their

Table 4-22. Estimated Number of Reference Program Employees During Regional Peak Employment, 1985

State/Region	No. of Rigs	Direct Employment[a]	Indirect Employment[a]	Induced Employment[a]	Total Employment	Local Hires[b]	In-Migrants	New Residents[c]
New York	2	143	104	988	1235	988	247	988
Pennsylvania	2	143	104	988	1235	988	247	988
Ohio	4	259	168	3416	3843	3075	768	3072
Region	8	545	376	5392	6313	5051	1262	5048

[a]Based on Table 4-21.

[b]Assumes 80% of workers will be hired locally.

[c]Assumes worker, partner, and two children.

Table 4-23. Estimated Number of Reference Program Employees in Ohio During Peak Employment, 1995

Type of Employment	Number[a]	Local[b]	In-Migrants
Direct	433		
Indirect	264		
Induced	1394		
Total	2091	1673	418

[a]Based on Table 4-21.

[b]Assumes 80% of workers will be hired locally.

families) are expected to reside around Cleveland, the projected port of activity. Cleveland and some of its adjoining suburbs that comprise Cuyahoga County are projected to have over a 1.5 million residents in 1990 (see Table 3-10). Again, these new residents will form an extremely small percentage of the county's total population and should not cause any social impacts to the county.

4.175
Based on the above evaluation of employment requirements and consequential changes to the region's existing social infrastructure, it is concluded that Reference Program activities should have no significant adverse impacts on urban quality, minorities, community development, community cohesion, and traffic patterns and transportation facilities.

Impacts of the Onland Alternative Program

4.176
The location of onland gas reservoirs is important in determining the severity and distribution of social and economic impacts. Residents within or adjacent to onland lease areas will personally experience potential effects from gas development and production activities. As found with other energy projects, local residents and their communities may be stressed by the demands placed upon them by the gas development activities. Other distant communities with economic, social, or political ties to the gas activity (e.g. county seat, regional metropolitan area) may be interested in expanding this economic activity. Various benefits may accrue to these cities with few costs.

4.177
If the adjoining towns and cities are large and stable areas, they should have the ability to provide services demanded by both transients and new residents. These capabilities will not be available in small rural communities.

4.178
The amount of development in an area will depend upon the size of the discovery. Extensive developments in a particular area will place greater demands upon the infrastructure of the local communities and adjacent residents than will small field developments. The length of time for developing the area can be a relevant factor in the severity and mitigation of impacts.

4.179
Onland developers will recruit local workers for many of their jobs. If the volume and required skills are not available from the local labor pool, a company may find it necessary to transfer some of its employees from other areas, solicit workers from outside the local area, and/or use local subcontractors for some of its work. The selection of an option(s) will produce different effects in the area. Transferring or soliciting workers will increase the local population and produce new demands on the local infrastructure. Those workers assigned to the area will probably return to their original residence and require few services. Employing subcontractors will add directly to the region's economic sector.

Regional Economy

Impact Sources

4.180
New York, Pennsylvania, and Ohio produced over 200 BCF of natural gas in 1977; increases in the wellhead price resulting from the Natural Gas Policy Act should increase future state gas production. The states have encouraged development of gas resources with the enactment of several policies. Ohio, for example, through the Public Utilities Commission, has mandated that East Ohio Gas Company supply 20% of all new residential and commercial customers with Ohio-produced gas. Ohio has also encouraged self-help gas production. Currently, 24% (28 BCF) of all natural gas produced in Ohio is self-help production.

4.181
The three states, however, are major net importers of natural gas, with over 2037 BCF delivered to consumers in 1977, and are heavily dependent upon traditional sources of gas supply. Many of the region's industries are dependent upon large and uninterrupted supplies of natural gas.

4.182
In Ohio, counties in the Reference Program Study Region are supplied by gas from the Columbia Gas Distribution Company of Ohio-Columbia Gas Transmission Corporation and the East Ohio Gas Company-Consolidated Natural Gas Company. Both transmission-distribution systems are largely dependent upon conventional southwest U.S. or Louisiana-produced gas. Eighty-seven percent of Columbia's gas supply comes from southwest or Louisiana sources; Consolidated receives 70% of its gas supply from southwest pipeline companies.

4.183
Although past efforts to plan for regional gas supplies by Columbia Gas of Ohio and the East Ohio Gas Company have generally been effective, there have been gas deliverability-supply problems in the region in recent years. Gas curtailments to large end-users were widespread, particularly during the heating seasons of 1976-1977 and 1977-1978 (McGregor et al. 1978). The recent gas availability crisis and imposed gas curtailments have focused public attention on availability-supply problems and underscored the need to develop alternative sources of natural gas.

4.184
A temporary surplus of natural gas has appeared which has resulted from some fuel switching, conservation measures, and a mature gas market, and no shortages are predicted at this time. However, the heavily industrialized Lake Erie region could experience a repetition of events that resulted in economic hardships for both employee and employer.

Impacts of the Reference Program

4.185
The development of a Lake Erie gas resource could provide additional supplies of gas and a degree of supply flexibility to the Reference Program Study Region. Because of the economics of gas distribution, it is likely that any gas produced in the Lake would be utilized by end-users within the 10-county

region. The maximum amount of Lake Erie natural gas produced under Reference Program assumptions is estimated at 1.5 TCF over the lifetime of the program (Table 4-24). This is a large natural gas resource that could augment conventional supply sources. From the perspective of large industrial end-users of gas, this is an important energy reserve that could be utilized in the event the region experiences future supply-deliverability shortfalls. The reserve could help provide supply flexibility for gas distribution companies in the Reference Program Study Region; consequently, supply flexibility could inspire increased industrial end-user confidence that regional gas utilities could maintain uninterrupted gas deliveries in the future.

Table 4-24. Projected Lake Erie Natural Gas Production

	Production Period (360 days/year)	Estimated Production (TCF)
New York	1980-2017	0.17
Pennsylvania	1980-2011	0.15
Ohio	1980-2033	1.2
Total		1.5

4.186
Based on the Reference Program, the price of Lake Erie natural gas is estimated at $2.47/million Btu in 1980. The price was escalated for different periods through the year 2000 by annual increments of 8.6 to 11.2% (see Chapter One - Economic Feasibility Analysis). Reference Program prices are expected to be competitive with other sources of natural gas and will cost less than nonconventional sources, LNG, or Alaskan gas.

4.187
As a result of the Reference Program, the three states will be able to augment their natural gas supplies at competitive prices on a financially attractive basis to industry. The economic feasibility evaluation conducted for the Reference Program indicates that U.S. offshore natural gas development is feasible, even when state rental and royalty fees and pollution control technology costs are included in the program. Cumulative state revenues from cash bonus bids, delay rental fees, and gas royalties would be $406 million for New York, $247 million for Pennsylvania, and $4290 million for Ohio. As described under the Reference Program regulatory assumptions (Chapter One - Assumptions Leading to the Definition of the Reference Program), an appropriate portion of program-generated state revenue will be used for financial support of state-administered regulatory programs, e.g., application processing, inspections, enforcement.

Impacts of the Onland Alternative Program

4.188
It is assumed that an Onland Alternative Program for the development of land-based gas resources in northern New York, Pennsylvania, and Ohio could produce a volume of gas similar to the volume produced from the Reference Program. The impact source would differ only in its location--land-based production as opposed to offshore Lake Erie production. This volume of gas would supplement conventional supply sources and provide supply flexibility to end-users. Increased regional land-based production could be stimulated as a result of wellhead price increases as provided by the Natural Gas Policy Act (NGPA). There is evidence that NGPA is having an impact on gas production within the three states. In Ohio, for example, 2606 new gas wells were drilled in 1978 (a record year for gas drilling), and 1900 new gas wells were drilled during the first six months of 1979 (Ohio Dep. Energy 1979). Increased self-help gas production could also provide additional land-based gas supplies to the Lake Erie region.

4.189
Ohio is presently producing 28 BCF of natural gas from self-help activity. This volume of gas is greater than Reference Program annual production from Ohio offshore lease areas except for the period between 1982 and 2001 (see Figure 1-18). Thus, a combination of factors could conceivably encourage annual production volumes of gas from regional land-based drilling similar to that of the Reference Program.

Summary

4.190
The following information is important for making decisions regarding development of U.S. Lake Erie natural gas:

- From the economic analysis, it appears that the Reference Program is economically viable. Even if the gas estimates in each lease area are off by 20%, there is a positive net present value and a rate of return higher than 11% in all lease areas except Lease Area XII, Case I.

- U.S. Lake Erie gas production will have only minor impact on national energy supplies but can be significant within local (New York, Pennsylvania, Ohio) gas markets.

- U.S. Lake Erie gas has the potential to displace a significant portion of high-priced SNG/LNG gas currently marketed in the three states. The National Fuel Gas Distribution Company currently sells 10.6 BCF annually of high-priced SNG/LNG at over $4.20/MCF. This represents nearly 8% of National Fuel's market in New York (Public Service Commission, NY) (Booz·Allen & Hamilton 1979). Ohio and Pennsylvania also depend on SNG and LNG to supplement a percentage of their total gas needs.

- U.S. Lake Erie gas has a projected annual production capacity of 29 BCF (from 1981 to 2033), which represents not only a significant percentage of the current SNG/LNG market but also a supply greater than the amount of gas curtailed in the three states in 1976-1977.

- Distributors and utility companies would probably purchase U.S. Lake Erie gas because they could pass on the higher price of new gas to the nonexempt industrial users as required by Title II of NGPA.

- "Local self-help" offshore gas development may be attractive to large industrial users who have seen the impact of curtailment in the form of plant shutdowns due to the lack of supply or pipeline deliverability, if the users perceive that U.S. Lake Erie gas is more economically attractive, provides greater assurances of continuous supply, and offers less risk than alternatives. This can be accomplished by means of FERC Order 533 which authorizes the commission to issue certificates of public convenience and necessity to interstate pipelines for the transportation of natural gas owned by an industrial end-user for use in its manufacturing plant.

CONFLICTS WITH OTHER PLANNED PROJECTS

4.191
The Reference Program, as designed, will begin in 1980 and continue into the first quarter of the 21st century. During this time frame, other projects will begin either in or abutting Lake Erie. These projects have been presented in Table 3-16.

4.192
Many of the projects listed in Table 3-16 have not been given a schedule; that is, they have been planned to occur at some indeterminate time in the future. An element of uncertainty about their acutal implementation is incorporated into their vague time frame; thus, it is not possible to predict whether there will be any conflicts between the Reference Program and these projects.

4.193
It is anticipated that the power plants planned to be constructed in New York and Pennsylvania will be completed within the next two decades. Other long-term projects, e.g., prevention of shoreline erosion and expansion of harbor facilities, will be or are being planned for in advance. Requirements for manpower, goods, and services will be small for the Reference Program and thus will not impede or conflict with any other proposed projects. However, improvements to harbor facilities and construction of an underwater electrical cable could be exceptions. If a harbor were being expanded, dredged, etc., planning would be required to prevent any problems in accommodating drilling rigs, service vessels, barges, and/or equipment storage. Lease sales will have to be designed to keep all gas development activities away from the planned underwater cable corridor (see Table 3-16).

UNAVOIDABLE ADVERSE IMPACTS OF THE REFERENCE PROGRAM

4.194
Pipeline construction will disturb 300-1300 ft of Lake Erie shoreline, preempting recreational use during the period of construction. Slightly accelerated shoreline erosion is expected in the immediate vicinity of pipeline landfalls. Local, short-term degradation of water quality will result from rig placement and removal, well stimulation, pipeline construction in the nearshore zone, removal of pipelines during decommissioning, and accidental releases of materials and residuals.

4.195
Wellheads on the lake bottom would complicate trawling activity in the vicinity of the wells. A maximum of eight rigs operating simultaneously would be temporary obstructions to navigation, and ships, barges, and service vessels would slightly increase harbor traffic. Diesel emissions from drilling rigs and gaseous emissions from drill stem tests and decommissioning procedures will degrade air quality near the rig; the effects will be slight, local, and temporary.

4.196
Rigs operating at distances slightly greater than one mile from shore could disrupt the "open sea" character of the Lake for some recreational boaters and people working, recreating, and living along its shore. Conversely, some people will perceive these rigs as interesting and visually pleasing phenomena.

4.197
Local short-term losses of benthic habitat and aquatic organisms associated with gas development would be unavoidable. These adverse effects would be temporary because organisms lost during construction will be replaced by natural reproduction and immigration from surrounding areas. Bioconcentration of toxic elements potentially contained in sediment may occur. However, considering the short duration of exposure, the small area affected, and the dispersion of resuspended material, significant adverse impacts are not expected.

4.198
Additional unavoidable adverse impacts include loss of land and associated loss of wildlife habitat committed to production facilities, onland pipeline corridors, and waste-disposal facilities. Noise from construction equipment, continual compressor operation, and annual underwater pipeline venting will be unavoidable.

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

4.199
The Reference Program will result in a permanent commitment of the land area occupied by a maximum of 10 gas production facilities. Slightly accelerated erosion rates at pipeline landfalls will permanently modify the landforms of bluffs. Intermingling of aquifers in the immediate vicinity of old wells will locally degrade water quality of aquifers beneath the Lake. Beach access provided by pipeline corridors will remain, even after pipelines are removed. Land disposal of wastes will preempt other uses of onland disposal sites. Plugged, abandoned wells will be permanent additions to the geological formations underlying Lake Erie.

4.200
Resources irretrievably committed also include materials consumed in the program that cannot be recovered or recycled using present technology. These resources include petroleum-derived fuels and oils; worn rig parts, including drill bits; and materials used for cement, drilling fluids, stimulation, and well completion. Production of natural gas will also constitute an irreversible commitment of a nonrenewable resource. Also, human resources will be committed to the design, construction, operation, maintenance, and decommissioning of gas development facilities.

RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF THE ENVIRONMENT AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

4.201
The objective of natural gas development in Lake Erie is near-term production of natural gas. Once produced, the resource is not renewed and is lost to future use. However, near-term use to counteract natural gas shortages predicted for the mid-1980s will also help counteract the perception of the Lake Erie region as an energy-deficient, economically declining region. This perceptual change would have long-term economic benefits when alternative gas supplies become more readily available in the long-term (post 1990).

4.202
Some impacts that would occur through the lifetime of the Reference Program--e.g., atmospheric emissions, noise, and potential operational accidents--will cease with program decommissioning. Production facilities and pipeline corridors may either be maintained for new similar uses, modified for new uses, or removed and reclaimed to near-original uses. Wastes disposed in onland facilities will remain after program decommissioning. Barring development of decontamination procedures applicable to these wastes, any impacts caused by continued waste storage will be borne by future generations.

MITIGATION OF REFERENCE PROGRAM CONSEQUENCES

Shorelands

4.203
The severity of impact to shorelands from pipeline landfalls can be controlled by (1) placement of the lines in areas of low erosion potential, (2) timing of construction, and (3) erosion control methods. Land-use conflicts and loss of wildlife habitat can be reduced by choice of landfall location, and impacts would be mitigated by use of corridors for public access to the Lake. Impacts from noise generated at production facilities can be mitigated by use of noise control technologies (enclosures, silencers) and special design considerations to maximize the buffering effects of terrain and vegetation.

4.204
Shoreline impacts resulting from landfall construction and decommissioning can be minimized or mitigated in the following manner:

1. Landfall location: Each of the 10 landfall sites must be carefully selected, using all applicable state and federal agencies and/or data reports that will aid in the selection. The shore type at the selected landfall site should be the one that exhibits the least erosion potential in the candidate area. If none are available, a minor tributary stream valley should be considered as the landfall corridor.

2. Corridor route: The corridor route should be planned to minimize disturbance to the topographic profiles.

3. Construction timing: Construction should be accomplished during periods or seasons of low lake level and/or low rainfall; in a stream valley, construction should occur during periods of low water level and between

spawning seasons. Construction should move at a brisk pace and take as little time as possible (prior design is essential).

4. Construction control measures: All appropriate erosion control and slope protection measures should be employed where feasible.

5. Shoreline protection: Where necessary or appropriate and acceptable, the landfall should be protected from erosion either by locating it in a broad natural beach or behind and updrift of an existing structure, or by erecting a new shore protection structure in the Lake.

Groundwater Hydrology

4.205
Contamination of groundwater would occur when casings fail. Thus, impacts can be avoided by good industry practices. The Reference Program waste management strategy--along with proper selection and design of waste treatment, landfill, and underground well injection sites--will minimize or avoid impacts to the quality of groundwater.

Water Quality

4.206
Mitigation procedures have been considered in the development of the Reference Program.

Aquatic Biota

4.207
Reference Program activities developed to protect water quality also protect aquatic biota. The potential impacts associated with well stimulation, resuspension during rig placement or removal and pipeline construction, disruption of habitat in pipeline burial, and release of fluids during well decommissioning will be small and short-term. Some impacts, i.e., disruption of habitat and resuspension, are unavoidable; however, careful planning and execution of good construction practices, equipment preparation, and waste disposal may reduce the magnitude of the resulting impacts to the biological community.

Water Use

4.208
Wellheads should be fitted with deflection devices to reduce the chance that commercial fishing gear would become entangled. Drilling has been excluded from areas commonly fished commercially.

4.209
Recreational use impacts may be mitigated by providing beach access along pipeline corridors.

4.210
Increased port traffic from the Reference Program would have a temporary beneficial impact on port facilities.

Terrestrial Ecology

4.211
The magnitude of impact from pipeline and production facility construction is highly dependent on site-specific characteristics. Careful siting and construction controls can greatly reduce terrestrial impacts.

4.212
For pipeline corridors that traverse the interface between the Lake and land, a possible mitigative action to decrease the risk of bluff erosion resulting from landfall construction might be the siting of these corridors within small, short tributaries. In some cases, this may mean a tradeoff between any natural values associated with the creeks and the values of having the shoreline erode more slowly.

4.213
A mitigation of the extensive use of herbicides for maintenance of a low grass-forb cover on the pipeline rights-of-way would be the selective use of herbicides plus selective cutting to maintain a cover of low-growing grasses, forbs, and bushes. Long-term maintenance costs will be lower, and fewer herbicides will contaminate land and water.

4.214
A possible mitigation for use of the few hazardous waste landfills in the region for disposal of drilling wastes would be to dispose of the drilling wastes in onland dredged spoil disposal sites. The relatively miniscule amounts of drilling wastes would not add significantly to the dredged spoil. Also, if the area was considered acceptable for dredged spoil disposal, it would inherently be acceptable for the less environmentally hazardous drilling wastes.

Land Use

4.215
Disposal of solid and liquid wastes, including drill cuttings and drilling muds, in onland landfills creates a land-use conflict because these sites are in short supply. Disposal of drilling muds and cuttings at onshore dredge disposal sites would reduce competition between gas developers and other users for landfill sites.

4.216
Land-use conflicts from construction of pipeline corridors and production facilities is highly site-dependent. Careful siting can greatly reduce land-use impacts.

Air Quality

4.217
Air quality impacts from the Reference Program are local and short-term in an uninhabitated area. No mitigation measures are suggested.

Esthetic Environment

4.218
Any structure introduced into the landscape can create a negative visual impact if not properly designed. Location, architectural style, color, and vegetative treatment can make any structure a negative focal point. Conversely, if properly designed from a visual standpoint, a structure can harmonize with the surrounding landscape. Camouflaging is a simple technique that, when applied properly to drilling rigs, could easily mitigate esthetic impact to the visual field experienced by any user group.

4.219
Gillespie and Clark (1979) assessed the visual impact of British oil and gas developments and concluded that structures colored to harmonize with surrounding environments are effective in mitigating possible esthetic impacts. Horizontal painted bands of blue color (ascending from dark to lighter shades) could be applied to the jack-up and floating rigs to break up the perceived verticality and create the impression that the rigs fade into the sky. Dark blue-green coloring of a rig hull would visually anchor and associate it with the surrounding water surface area. Progressively lighter blue colors ascending up the tall vertical structures (derricks, cranes, and jack-up leg extensions) would tend to merge the framework with clouds in the background sky. This type of treatment is most applicable when rigs can be viewed from onshore settings.

4.220
Another painting scheme best adapted to the open water setting involves the use of primary bold colors. Brightly colored structures in a monotonous seascape can provide a sense of place and location, a landmark for orientation, and a stimulus for visual excitement (Cairns and Associates 1974).

4.221
Proper landfall site selection involves the analysis of shoreline with the intention of defining and avoiding any special scenic, historic, and biotic landscapes that possess the potential to provide pleasing esthetic opportunities for public use. Proper site analysis should consider the possible landforms involved in siting and the perspective user groups to be affected by landfall elements. Grouping landfall elements with existing man-made facilities would greatly reduce esthetic impacts in the shoreline viewsheds (e.g., Reference Program pipelines could be brought onshore adjacent to existing jetties or breakwaters). Opportunities to provide visual buffers for exposed pipeline protection structures should also be considered. Shoreline settings possessing high potential for negative impact include wetlands, waterfowl habitats, natural stream corridors, and unique wildlife areas.

4.222
The visual impact of lakeshore facilities required by the Reference Program--such as temporary service bases, repair and maintenance yards, and pipeline installation bases--will be kept minimal if railyards or other existing facilities are utilized. Pipeline corridor impacts can also be greatly reduced if existing opportunities are employed (e.g., laying pipelines along existing utility corridors or adjacent to railways or roads). Where pipelines must penetrate vegetated areas, undulation of the corridor edges to break up the linear pattern is another possible measure to induce a more natural feeling.

4.223
Reference Program gas processing and treatment facilities should in no way be associated with the land/water interface except where their visual characteristics will blend well with similar forms of an industrial or urban nature. Ideally, their site location should be close enough to shoreline to minimize pipeline corridor length and far enough from the interface zone so as not to be seen from water and shoreline areas.

Cultural Resources

4.224
Cultural resource mitigation plans should be developed for the lease areas. Specific guidelines for the design of cultural resource mitigation programs for select lease areas are being developed at this time.

Demography and Socioeconomics

4.225
Impacts are predicted to be so slight that no mitigation is suggested.

Regional Economy

4.226
The Reference Program is predicted to have beneficial impacts on the regional economy; thus, no mitigation is suggested.

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CHAPTER SIX: PUBLIC INVOLVEMENT

BACKGROUND

6.001
During the period between late 1975 and early 1977, the Buffalo District, U.S. Army Corps of Engineers, received inquiries regarding U.S. Lake Erie gas development from various New York, Pennsylvania, and Ohio groups, individuals, agencies, and Congressmen. Most of the letters or telephone calls were received in 1977 and requested information on the Corps' position and regulatory jurisdiction relative to gas development activities in Lake Erie. These early contacts included: Senator James T. McFarland, New York State Senate; the New York State Department of Environmental Conservation; the Lake Erie Basin Committee, League of Women Voters; the City of Dunkirk; Citizens for Clean Air and Water, Ohio; Senator Anthony Calabrese, Ohio State Senate; Schafer Exploration Company, Ohio; and the Pennsylvania Department of Environmental Resources. During these early periods, gas development in Lake Erie was prohibited by the States. The Buffalo District Office responded to the inquiries and also began an internal scoping process to identify issues of concern. This internal scoping ultimately lead to the preparation of an environmental guide outlining issues and data needs. The guide was distributed to federal and state agencies and other interested parties for review and comment. While the Corps was performing this task, the states of New York and Pennsylvania lifted existing bans on offshore drilling (1977). In early August 1977, the U.S. Environmental Protection Agency Headquarters, Washington, DC, expressed an interest in coordinating with the Buffalo District Office on Lake Erie gas development studies. This culminated in an Interagency Agreement to study the issues and prepare a generic environmental impact statement. The Great Lakes National Program Office, USEPA Region V, was designated as the coordinating office. Ultimately, the Division of Environmental Impact Studies, Argonne National Laboratory, was selected as the consulting contractor.

SCOPING MEETINGS

6.002
The scoping meetings which were held for this study included representatives of the U.S. Department of Energy, U.S. Department of Transportation, U.S. Fish and Wildlife Service, U.S. Department of Commerce, Great Lakes Basin Commission, Pennsylvania Department of Environmental Resources, New York State Department of Environmental Conservation, Ohio Department of Natural Resources, and the Lake Erie Basin Committee of the League of Women Voters. These meetings were held on August 15, 1977; October 3, 1977; August 21, 1978; and December 14, 1978. Significant issues identified during the scoping process focused on water quality, aquatic ecology, energy availability, need for gas, cultural resources, recreation, navigation, economics, and land-use changes in the coastal zone. Overall, the meetings and technical review have assisted in the development and analysis of data contained in this Environmental Impact Statement. Interagency coordination efforts will not terminate with the issuance of the Draft Environmental Impact Statement. Instead, these efforts will be continued up to the point that a decision is made on the acceptability of gas development in Lake Erie, and possibly beyond the point of decision, if necessary.

ISSUES IDENTIFICATION REPORT

6.003
A report related to the overall study was completed in September 1978. This report is entitled "An Examination of Issues Related to U.S. Lake Erie Natural Gas Development" (prepared by Argonne National Laboratory, Division of Environmental Impact Studies). The authors of the report described gas development activities, identified various issues of environmental concern, presented economic overviews, and discussed the potential for natural gas resources beneath Lake Erie. The report was distributed to the scoping team representatives for review and comment. Additionally, the availability of this report was mentioned in the Corps-USEPA notice of intent to prepare an EIS (Federal Register Vol. 44, No. 147, p. 44593, July 30, 1979). Several hundred requests for the initial report have been filled since the publication of the notice of intent, and the names of these requesting individuals, groups, organizations, and agencies were placed on the project mailing list to receive future public notices.

PUBLIC HEARINGS

6.004
To gain public involvement and input and to inform the public of the study, public hearings were held as follows: Toledo, Ohio, on October 16, 1979; Cleveland, Ohio, on October 23, 1979; Erie, Pennsylvania, on October 30, 1979; and Buffalo, New York, on November 1, 1979. Prior to the hearings, information related to gas development activities and potential effects of development was made available to the public. The major concerns raised during these hearings included disposal of residuals, accidents, navigation, water quality, water supplies, disturbance of toxic sediments, alternatives, seismology, effects of ice, administrative and regulatory procedures, economics, and need for availability of gas resources beneath Lake Erie. These concerns are addressed in this Environmental Impact Statement.

MEDIA COVERAGE

6.005
The overall project has been given coverage by newspapers, radio stations, and television stations throughout the affected area. The study has also been described or cited in the USEPA publication "Environment Midwest," the Great Lakes Basin Commission publication entitled "The Great Lakes Communicator," and a University of Wisconsin-Madison, Department of Agricultural Economics, article on Lake Erie gas development (J.B. Braden, and D.W. Bromley, December 1979).

DISTRIBUTION LIST

6.006
To ensure full coordination, this Environmental Impact Statement has been sent for review and comment to the federal, state, and local government agencies, environmental groups, private industries, and individuals listed below:

FEDERAL AGENCIES AND OFFICIALS

U.S. Dept. of Agriculture	Great Lakes Basin Commissior
U.S. Dept. of the Interior	Nuclear Regulatory Commissi

U.S. Environmental Protection Agency
U.S. Dept. of Commerce
U.S. Dept. of Transportation
U.S. Dept. of Housing and Urban Development
U.S. Dept. of Health, Education and Welfare
U.S. Dept. of Energy
U.S. Dept. of Labor
U.S. Dept. of State
Water Resource Council
Federal Emergency Management Agency
Appalachian Regional Commission
General Services Administration
Interstate Commerce Commission
National Endowment for the Arts
Advisory Council on Historic Preservation
Federal Programs Office - Coastal Zone Management
Federal Regional Council
National Aeronautics and Space Administration
U.S. Senator Daniel P. Moynihan
U.S. Representative Jack F. Kemp
U.S. Senator Howard M. Metzenbaum

INTERNATIONAL INTERESTS

International Joint Commission, Washington, DC
Canadian Embassy, Washington, DC
Ontario Ministry of Natural Resources

STATE OF NEW YORK

Coastal Zone Management Office, Dept. of State
New York State Department of Environmental Conservation, Bureau of Mineral Resources
New York State Energy Office
New York State Office of Parks and Recreation, State Historic Preservation Officer
New York State Department of Health
New York State Department of Public Service
New York State Department of Environmental Conservation, Office of Environmental Analysis
State Clearinghouse, Division of Budget
New York State Sea Grant Program, SUNY Albany
Office of the State Archeologist
Department of Agriculture and Markets
New York State Department of Transportation
Office of General Services, New York State Executive Department
New York State Department of Commerce
New York Job Development Authority
New York State Geological Survey
New York State Assembly Subcommittee on Public Power
Honorable Ronald H. Tills

COMMONWEALTH OF PENNSYLVANIA

Pennsylvania Department of Environmental Resources, Assistant State Geologist
Pennsylvania Department of Environmental Resources, Bureau of Forestry, Mineral Section
Pennsylvania Department of Environmental Resources, Division of Dams and Encroachments
Pennsylvania Department of Environmental Resources, Coastal Zone Management Branch

Pennsylvania Historical & Museum Commission, State Historic Preservation Officer
Pennsylvania State Clearinghouse, Governor's Office
Pennsylvania Fish Commission
Pennsylvania Department of Transportation
Coastal Zone Management Program, Edinboro State College
Pennsylvania Game Commission
Pennsylvania Department of Commerce
Pennsylvania Department of Agriculture
Governor's Energy Council
Pennsylvania Department of Health
Pennsylvania Department of Community Affairs

STATE OF OHIO

Ohio Department of Health
Ohio Department of Transportation
Ohio Department of Natural Resources (ODNR), Division of Oil and Gas
State Clearinghouse, Office of Budget and Management
Ohio State Historic Preservation Office
Ohio Department of Natural Resources, Division of Water
Ohio Environmental Protection Agency
Ohio Department of Natural Resources, Coastal Zone Management Office
Ohio Department of Agriculture
Ohio Department of Energy
Ohio Department of Economic and Community Development
Ohio Department of Administrative Services, Bureau of Real Estate
Honorable Anthony O. Calabrese, Ohio Senate
Honorable Dennis E. Eckart, Ohio House of Representatives

STATE OF MICHIGAN

Michigan Department of Natural Resources

REGIONAL, COUNTY AND LOCAL AGENCIES

Erie and Niagara County Regional Planning Board, New York
Erie County Energy Office, New York
Chautauqua County, Planning and Development Agency, New York
Erie County Environmental Management Council, New York
Southern Tier Western Regional Planning-Development Board, New York
Northwest Pennsylvania Regional Planning and Development Commission, Pennsylvania
Erie County Metropolitan Planning Commission, Pennsylvania
Lorain County Regional Planning Commission, Ohio
Ashtabula County Planning Commission, Ohio
Cuyahoga County Regional Planning Commission, Ohio
Erie Regional Planning Commission, Ohio
Northeast Ohio Areawide Coordinating Agency, Ohio
Ottawa Regional Planning Commission, Ohio
Lake County Planning Commission, Ohio
Sandusky County Regional Planning Commission, Ohio

ORGANIZATIONS

Great Lakes Laboratory, State University College at Buffalo
League of Women Voters
Natural Resource Defense Council
National Wildlife Federation
Izaak Walton League
Sierra Club
National Audubon Society
Lake Eire Alliance for the Protection of the Coastal Corridor (Downwind Neighbors)
Stone and Webster Engineering Corporation
Columbia Gas System Service Corporation
Hammermill Paper Company
University of Illinois at Urbana-Champaign (Department of Agricultural Economics)
University of Waterloo, Environmental Studies, Ontario
Pennsylvania Electric Company
Michigan State University, Resource Development Department

PUBLIC NOTICE MAILING LIST

6.007
The mailing list of those interested in receiving public notices of availability of this draft programmatic Environmental Impact Statement is extensive and could not reasonably be included in the text. The mailing list is on file at the Buffalo District Office, 1776 Niagara Street, Buffalo, New York 14207, and is maintained in the Regulatory Functions Branch. The list includes news media; mayors; organizations; local agencies; post offices; individuals; environmental groups; companies and corporations; federal, state, and local government officials; libraries; universities; and consultants, principally in New York, Ohio, Pennsylvania and Michigan. All those who have contacted the USEPA or Buffalo District for information on gas development or attended the public hearings are on the notice of availability list. In addition, to facilitate public access, review, and comment on this statement, copies of this draft EIS have been placed in 29 information centers (libraries, Corps offices, town halls) along the Lake Erie coastline from Buffalo, New York, to Detroit, Michigan.

APPENDIX A. DESCRIPTION OF NEW YORK STATE AND COMMONWEALTH OF PENNSYLVANIA OFFSHORE LAKE ERIE REQUIREMENTS UNDER PROPOSED LEASES OR OPERATIONAL RULES AND REGULATIONS

Table A.1. Description of New York State and Commonwealth of Pennsylvania Offshore Lake Erie Requirements under Proposed Leases or Operational Rules and Regulations[a]

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
1. Enabling legislation	1. Article 23, N.Y.S. Environmental Conservation Law	1. Act 275, P.L. 834, 71 P.S., Section 1902-A, 3 December 1970
2. State-owned land	2. 373,000 acres	
3. Potentially leasable land	3. 93,250 acres	
4. Rights and privileges granted by lessor	4a. Production of natural gas only b. No gas storage rights c. No liquid hydrocarbons d. Lessee will be granted rights of first refusal in the event that gas storage or oil production are allowed	4a. Exploration, drilling, operating, producing, removal, and disposal of natural gas b. No production of oil, condensate, or wet gas c. The right to use lease for gas or LPG (fluids) storage is expressly reserved by the Commonwealth of Pennsylvania d. Lessee has right of first refusal for any oil production lease on surrendered acreage e. In the event that DER judges a tract feasible for storage, the well equipment and casing involved must be offered to DER at fair market value 30 days prior to commencement of equipment removal or any plugging by lessee f. Lessee may use water and gas from lease area free from royalty to run drilling machinery g. DER reserves oil and all minerals and substances within the leased premises other than natural gas and shall have the right to lease those rights to third parties subject to rights granted to lessee under this lease h. Surface rights of DER shall be considered dominant and mineral rights of lessee servient i. Any dispute between parties concerning surface use shall be resolved in favor of the public interest
5. Lease unit definition	5a. Tract: 1 minute latitude 1 minute longitude 626 acres on average b. Block: 5 minutes latitude 5 minutes longitude 25 tracts	5. Tract: 1 minute latitude 1 minute longitude 630 acres on average

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
6. Lease terms	6a. Primary term of 10 years b. Secondary term of 5 years	6a. Primary term of 10 years b. Extension on a year-to-year basis as long as gas is being produced or drilling, reworking or abandonment operations are under way c. Primary term may be extended for 6 months if weather delays drilling operations
7. Bonus payment	7a. One-time bonus bid in lieu of first year rental b. Must be greater than $2 per acre	7a. One-time bonus bid in lieu of first year rental
8. Rental payment	8a. Primary term: $2 per acre per year b. Shut-in rental: $2 per acre per year up to 5 years	8a. $1 per acre per year b. Deduction for acreage attributed to drilled wells or unitized fraction c. Shut-in rental: $2 per acre per year
9. Royalty payment	9a. 16.7% of gas produced or 16.7% of market value of gas b. Payable semiannually c. If production is below royalty requirement, delay rental may be used up to 5 years	9a. 12.5% of market value of gas or $1.18 per MCF, whichever is higher b. Payable on the 25th of each month for production from the preceding month c. At option of DER, payment may be in gas
10. Method of sale	10a. Competitive bidding b. Lease will be sold to highest qualified bidder c. Formal execution of lease 3 months after public opening of bids d. Organizational report required from bidder e. Nomination fee of $25 per tract is required f. A refundable deposit of 10% of bid is required	
11. Liability		11a. Lessee shall be alone liable and responsible for any pollution or other damage unless an independent intervening cause is found to be the sole proximate cause of the pollution or damage b. In civil suits, burden of proof is on lessee to demonstrate evidence to rebut presumption of responsibility for damages
12. Tie bids	12. Tie bidders may either jointly own lease or choose one owner by chance or negotiation	

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
13. Drilling and offset requirements	13. None	13a. If first well is productive, a subsequent well must be drilled to the producing formation on the leased premises b. If DER determines a subsequent well is needed, lessee has the option of drilling within 6 months or surrendering acreage covered by lease except for 630 acres around each productive well c. Unless waived by DER, lessee must drill offset wells to prevent drainage to wells within 2260 ft from lease boundary that are producing gas owned by N.Y., Ohio, or Ontario
14. Unitization and transfer of ownership	14a. Adjacent tracts may be unitized b. Ownership of tracts may be transferred with approval from DEC	14a. Adjacent tracts may be unitized with approval of DER b. Royalties for unitized production will be allocated on an acreage ratio basis
15. Relinquishment by lessee	15a. A tract may be surrendered upon 30-day prior written notification b. No refund of rental or royalty	
16. Termination of lease	16a. If lessee fails to make rental payment within 30 days after notification of being past due b. At the end of primary term if well is not capable of commercial production c. During secondary term if lessee fails to make royalty payment within 30 days after notification of being past due d. During secondary term after 5 years of noncommercial production e. 30 days after receiving written notice by DEC that lessee has been found guilty of a violation of tenancy, lease terms, DEC rules and regulations (Article 23), provided that lessee has not abated violation and paid penalties, fines, or damages assessed	16a. If well is not commenced within 5 years of lease initiation, - well must be drilled through Ordovician Queenston Formation - gas may be produced at shallower depths b. If not in default of any obligations if written notification is made to DER 30 days prior to termination date and all lease commitments are fulfilled ("first well" provision is not a commitment) c. Money paid as advance bonus or land rental previous to termination date will be prorated or returned d. In the event that producing wells are to be retained, lessee may retain that drainage acreage attributable to each well - lessee shall be relieved of all obligations and rental fees accruing to surrendered acreage - lessee shall not be relieved of any obligation which accrues prior to such surrender even if the result caused by lessee's performance or failure of an obligation becomes apparent after surrender

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
17. Enforcement	17a. DEC representative has the right to remain aboard a drilling vessel to observe and take appropriate action to administer rules and regulations b. DEC will repay operator for services rendered to representative c. Representative has the right to take appropriate administrative action to eliminate a risk of pollution or environmental threat d. Any pollution, environmental damage, or uncontrolled escape of natural gas or formation fluids that may result from operator's failure to act on representative's orders shall be considered willfull violation of regulations	17a. Whenever an inspection shows that the casing or control equipment at a well is not adequate, DER may prescribe remedial measures which shall be complied with before resumption of drilling b. DER reserves the right to use leased premises in any and all respects not specifically limited by lease terms c. DER reserves the right to approve in writing all plans for the construction upon leased premises of structures, rigs, machinery, communication facilities, well locations, pipelines, and equipment for drilling of wells d. Detailed written plans must be submitted 30 days prior to planned commencement unless otherwise approved by DER
18. Access to property and records	18a. DEC has the right to enter and reasonably inspect and investigate any tract, drilling vessel, tank farm, pump station, pipeline, or compressor plant during normal working hours or anytime in case of emergency b. DEC has access to well records, well logs, well samples, directional surveys, reports on well locations, well tests, production statistics c. If requested by operator, DEC will not disclose above information except as may be used in legal or official proceedings	18a. Lessee grants to DER the right at any time to examine, audit, or inspect books, records, and accounts of lessee pertinent to the purpose of verifying the accuracy of reports and statements furnished to DER and for checking the amount of payments lawfully due under the lease terms b. Lessee must provide every aid and facility to enable such an audit c. If such an audit discloses any gross error or fraud by lessee in payment of royalties, lessee shall pay cost and expense of audit and deficiency d. In the case of fraud by lessee, payments shall not preclude DER in its discretion from cancelling the lease upon written notice e. The people of Pennsylvania have some access to lessee's facilities and relevant records for the purposes of inspection when in accompaniment of a DER representative provided: - access is to lessee's facilities on leased premises limited to nonhazardous areas during normal business hours - written approval by lessee - access to records shall be limited to those which are nonconfidential in nature

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
19. Permits	19a. A Permit to Drill is required prior to commencing to drill, deepen, plug back, or work over a well for exploration or production b. DEC shall issue Permit to Drill upon determination that requirements of bonding insurance, organizational report, contingency plan and other agency approvals have been satisfied c. Permits to Drill become effective May 1 and expire October 31 (6 months) d. No work may commence after October 15 e. Permits received after September 30 shall not be valid until May 1 of the following year f. Permit to Drill does not supersede permit requirements from USCG, USCOE or other agencies with jurisdiction	19a. No well shall be commenced, deepened, reopened or plugged back without written authorization by DER and permits by DER (Bureau of Land Protection, Div. of Oil and Gas, Bureau of Water Quality Management, Div. of Water Quality, Div. of Dams and Encroachments) and USCOE b. Prior to commencing drilling operations, lessee must submit a work plan covering the following components to DER, USCG, and USCOE: well location; well designation; well objective; drilling work plan; waste disposal plan; casing and cementing plan; plugging and abandoning plan c. Terms of permit will be April 1 through October 31 (7 months) d. Lease does not release lessee from obligations to obtain USCOE permits for drilling, dredging or filling, buoys, pipelines, drilling rigs or platforms, docks, cofferdams, piers, bulkheads, wellheads, etc.
20. Organizational reports	20. Operator and contractors must file organizational information with DEC for all activities related to exploration, development, production, abandonment and salvage	
21. Bonds	21a. Plugging bond of $50,000 for each well b. Pipeline removal bond of a reasonable amount for each line located within 0.5 mile from lakeshore c. In lieu of bonds, operator may deposit cash, certified check, negotiable bond, treasury certificate, treasury bill or acceptable substitute	21a. Surety or performance bond with satisfactory corporate surety of $40,000 for each lease b. Surety or performance bond of $20,000 prior to commencement of each well on leased premises c. Upon satisfactory permanent abandonment of each well and adequate restoration of affected area, bond deposited will be reduced by $20,000 d. In the event that lessee shall fail to remove its equipment and machinery and properly abandon the well, bond may be used for cost of removal and proper abandonment e. Bond may be used for all damages that may arise as a result of fires, accidents, or any other causes brought about by lessee or its agents f. Failure to comply with plugging requirements will be reason for cancellation of lease and forfeiture of bond for proper plugging by DER

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
22. Accidental discharge insurance	22a. Operator must furnish proof of liability insurance of $1 million for each adverse occurrence b. Insurance shall remain in force until all wells have been plugged and abandoned to the satisfaction of DEC c. An acceptable substitute may be used in lieu of insurance; cash, certified check, negotiable bond, etc.	22a. Lessee shall maintain in force an insurance policy of $1 million which will cover accident and property damage liability resulting from each adverse occurrence or accident which may occur during any operation, including exploration, drilling, producing, and delivering the well product, conducted pursuant to lease
23. Well spacing	23a. No more than 4 wells per tract unless otherwise authorized by DEC b. Wells must be at least 1320 ft apart at lake surface c. Wells must be at least 660 ft away from tract boundary at total depth d. A spacing order establishing specific well density may be promulgated by DEC on its own volition or in response to operator request	23a. Lessee shall not be required to drill more wells than required or allowed under any DER spacing order, rule, or regulation or in absence of such order more than 1 well per 630 acres b. 1 well per tract unless otherwise permitted c. Wells must be at least 660 ft from tract boundaries or the distance corresponding to radius of drainage defined by DER d. First well should be located in center of tract e. Well spacing is subjected to regulations and restrictions by USCG and USCOE in regard to shipping lanes, construction, dredging and other areas under jurisdiction
24. Drilling restrictions	24a. Wells must be at least 0.5 mile from shore or from a potable water intake b. Wells must be at least 1000 ft from any other structure or installation (including outfalls) c. Wells must be at least 0.5 mile from a state or international boundary d. All well locations are subject to restrictions by USCOE or other federal agencies with jurisdiction	24a. Wells must be at least 0.5 mile from state or international boundaries except through permission of DER b. A restricted area around Presque Isle Peninsula is prohibited from drilling
25. Drilling method	25a. Rotary drilling only b. Drilling vessel and equipment must be in compliance with DEC, USCG, and USCOE rules and regulations	25. Lessee must drill a straight hole to the best of lessee's ability
26. Well location	26. Visual and electronic survey techniques must be used to confirm well location	26. Well location must be surveyed to the nearest 0.5 second of latitude and longitude by precise survey methods

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
27. Well identification	27. Operator's name, tract designation, and well number must be displayed in at least 2 places on the rig visible at least 500 ft away	27a. Name of lessee, name and number of well or facility, number of all USCOE permits, and description of well or facility by latitude and longitude must be conspicuously located on all structures and facilities b. Wellheads must also be identified to the satisfaction of DER
28. Commencement notification	28. DEC must be notified 24 hours prior to commencement of any permitted activity	28a. Lessee must make daily drilling reports to DER on plans or information regarding drilling, cementing, logging, testing of casing, acidizing, fracturing, completion, and plugging b. Operations shall not commence until a DER contact is established
29. Prevention of pollution	29a. Drilling, casing, and completion programs must be adequate to prevent discharges and emissions in excess of DEC rules and regulations and to prevent migration of indigenous formation fluids from one subsurface stratum to another b. All materials except unadulterated lake water, most cement slurries, and clean rock cuttings (which can be discharged to the Lake) must be stored aboard and disposed of onshore in compliance with appropriate regulations	29a. Lessee shall at all times maintain casing control equipment that will effectively control any oil, gas, or water encounters b. All casing, tubing, and equipment used in the drilling and completion of a well should be in good condition and adequate in strength for depths to be drilled and pressures that may be encountered c. Drilling operations, including setting and cementing of casing, shall produce gas without waste and take all reasonable precautions to use proper equipment and practices as will protect persons and property against fires and hazards from blowouts d. Lessee shall agree that during production operations and during the delivery of gas to the market, the lessee shall keep, maintain, and repair its wells, pipelines and equipment to the end that there shall be no leaks or waste of natural gas or discharges of polluting substances
30. Liquid hydrocarbons	30a. Production of liquid hydrocarbons either alone or associated with natural gas is prohibited b. If there is evidence of liquid hydrocarbons during drilling or completion, operations shall immediately cease, muds (if not already in use) shall be pumped to displace all lake-water drilling fluid	30a. All wells encountering oil, condensate, or wet gas shall be plugged or those zones capable of producing the above cemented off b. With DER consent, lessee may continue to explore for natural gas in shallower strata above oil encounter

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
30. Liquid hydrocarbons (continued)	30c. Displaced wellbore fluids may be discharged to the Lake only if not contaminated by liquid hydrocarbons d. DEC must be notified of evidence indicating liquid hydrocarbon shows e. Formation test conducted under DEC supervision will determine presence of liquid hydrocarbons f. If a production potential of 5 gallons or more per day of liquid hydrocarbons is discovered, wellbore must be cemented to total length g. If production potential is less than 5 gallons per day, operations may be resumed after formation is cased off and pressure tested	
31. Drilling fluids	31a. Only liquid drilling fluids are permitted b. Every drilling vessel shall have aboard, ready for immediate use, a closed mud system equal to 150% of the wellbore volume of sufficient density to stop formation fluid flow c. Prepared muds and closed system are required when drilling through rock salt, strata containing fluids other than fresh water, and when conditions require addition of chemicals, dissolved or suspended minerals, preservatives, hydrocarbons, or other materials deleterious to lake biota d. Unadulterated lake water drilling fluids and cuttings may be discharged except when fluid or cuttings are expected to contain deleterious amounts of dissolved or suspended minerals or formation fluids	31. Drilling mud of sufficient weight to prevent oil, gas, or water blowouts, or flows to the surface shall be mixed and ready to use in wells prior to drilling any reservoir deemed by DER to be capable of flowing liquid or gas to the surface
32. Casing programs	32a. Casings, casing heads and fittings must conform to API standards with working pressure capabilities of at least 2000 psig b. All casing strings must be cemented from total depth to lakebed c. After 12 hours of waiting on cement, casing must conform to pressure test of not more than a 10% pressure drop in 30 minutes d. Surface casing must be set at least 100 ft into bedded rock or below the deepest freshwater aquifer, whichever is deeper	32a. All wells must be equipped with casing heads of rated working pressure not less than 28% greater than maximum rock pressure anticipated or rated to withstand test pressure exceeding by 10% the maximum well treatment or stimulation pressure anticipated, whichever is greater b. Casing head must have adequate connections and valves to permit pumping of mud-laden fluid between any 2 strings of casing at the surface

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
32. Casing program (continued)	32e. Surface casing must be set with 50 sacks of cement in excess of calculated annular space volume behind the casing f. Surface casing must be pressure tested to 40 psig g. Intermediate casings must be set for liquid hydrocarbon strata, strata with uncontrollable flows, or lost circulation zones h. Intermediate casings must be tested to 100 psig i. Production string is required if well is to be completed j. Production string must be cemented to total depth and pressure tested at 1000 psig or 200 psig in excess of well's expected shut-in pressure, whichever is higher	32c. Reconditioning is required when casing head pressure is of hazardous proportions or indicative of underground waste or if leakage of oil or gas between the producing string and next larger string is of hazardous proportions d. No casing shall be perforated until adequate control equipment (Master Valve and Lubricator or their equivalent) has been installed and is in working order e. Lessee must use a casing program which complies with oil and gas statutes, rules, and regulations of Pennsylvania and which prevents escape of oil, gas, or water out of one stratum into another, the pollution of fresh-water supplies, and blowouts f. Conductor string must be driven into the lakebed g. Surface casing must extend from surface to a depth below all freshwater zones known or believed to exist in the area h. Intermediate strings must be set inside surface casing if necessary to confine any gas, oil, or water originating from intermediate horizons or to protect such horizons from high pressures prior to setting and cementing production string i. Intermediate strings may be cemented through any potential producing horizon with approval from DER j. Production casing must be of seamless pipe of a grade and weight designed to meet following pressures - maximum anticipated rock pressure should not stress casing greater than 75% of API specified internal yield pressure of pipe at minimum yield - for wells to be fractured, fracture pressure anticipated must not exceed API internal yield pressure of casing at minimum yield k. After cementing and before perforating or drilling-in, casing must be tested by pump pressure at the wellhead to a pressure 20% greater than anticipated maximum pressure at the wellhead and at least 1000 psi

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
32. Casing program (continued)		32l. After 30 minutes, pressure drops of greater than 50 psi must be repaired m. Surface and production casing must be cemented in compliance with API specifications by pump and plug procedures or procedures approved by DER n. In cementing surface casing, an attempt must be made to circulate casing cement to the lake bottom surface o. In the event that cement cannot be circulated to the surface due to the presence of fractures or other lost circulation zones, lessee shall determine depth of top of cement in annular space behind casing and record it on the well record p. In wells where cement has not been circulated to the surface, there must be sufficient cement to tightly hold the casing in place to prevent the escape of oil, gas, or water from one stratum to another or to the surface q. Sufficient cement shall be used above the casing shoe to fill the calculated annular space behind the casing by an excess of 15% r. If producing string is set through all known producing formations, a minimum of 20 ft of cement shall remain in the bottom of the casing s. Cement shall be allowed to stand a minimum of 24 hours before drilling the plug or initiating tests (this period may be shortened with DER approval)
33. Blowout prevention	33a. No operation shall be conducted in a wellbore after surface casing has been set and until production casing is cemented unless fully protected by a blowout preventer (BOP) with a working pressure capacity at least 200 psig in excess of the well's expected shut-in pressure	33a. All drilling and service wells must be equipped with BOP equipment, tested to twice normal hydrostatic pressure at working depth, that will completely close off the open hole and close around any equipment being employed in the well

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
33. Blowout prevention (continued)	33b. When equipped with proper remote controls, BOP may be installed either on lake bottom or on drilling vessel c. Minimum BOP requirements: - 2 dual-controlled hydraulic ram-type preventors (blind ram and pipe ram) - 1 annular BOP - 1 rotating head - appropriate choke and kill valves d. Kelly cock and an inside flapper or dart valve must be used for insertion into drill pipe when kelly is removed e. Hydraulic ram-type preventors must be exercized before each trip and at least once every 25 hours f. BOP must be pressure tested upon installation of each casing string	33b. BOP equipment must be capable to shut-in the well at a point at least 50 ft from the well-head c. If BOP is hydraulically operated, adequate pressure must be maintained at all times d. BOP must be equipped with a bleed-off valve of proper size and working pressure e. While a well is being drilled with mud or water as a drilling fluid, lessee shall test control equipment daily to the extent possible without causing premature removal of drill pipe from the hole; the results of such tests shall be recorded daily
34. Formation testing	34a. Drill stem tests take place only during daylight hours b. Formation fluids recovered during the test must be separated from natural gas and stored aboard for appropriate land disposal c. No formation fluids other than fresh water may be discharged to the Lake d. Natural gas produced during testing shall be flared	34a. Well shall not be allowed to blow open, except in case of an emergency, over 24 hours after drilling-in to a gas reservoir b. Regular royalty will be paid on any gas allowed to escape after 24 hours except in case of an emergency not caused by the lessee c. After initial open-flow test has been taken, potential shall be made by U.S. Bureau of Mines Back Pressure Test Method or by other methods standard to industry and approved by DER d. Determination of initial open-flow potential shall be made before any attempts are undertaken to increase flow through stimulation
35. Well completion	35a. All wells to be completed for production shall use total depth production casing (no open-hole completions will be allowed) b. Wellheads and tubing must have a working pressure capacity at least 200 psig in excess of shut-in pressure c. No permanent platforms or other structures shall be permitted on the lake surface d. Wellheads must be installed on or under the lake bottom and may not extend more than 5 ft above the surrounding lakebed	35a. All reasonable precautions shall be taken before a well is drilled into a potential gas reservoir to control waste and prevent contamination of the Lake by oil, gas, or well fluids b. Reasonable provisions shall be made for installing producing equipment before a well is placed on production c. Lessee shall ensure that the production casing is cemented to the surface before production commences

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
35. Well completion (continued)	35e. Trawl deflectors will be installed when required by DEC f. Wellheads must be equipped with full opening ball valves on the tubing and on the annular space between tubing and production casing string (ball valves must have bleed valves of equal working pressure capability) g. Completed wells must have subsurface safety valves or storm chokes in the tubing string (DEC can require valve inspection) h. Wellheads must be inspected and tested for proper functioning once each calendar year after installation	35d. Lessee shall complete and connect all producing natural gas wells to pipelines as near as practical to the level of the lake bottom e. Wellhead is to be encased in a cellar below lake bottom f. Upon written approval from DER, the maximum height of the wellhead assembly above the lakebed may be 2-1/2 ft g. All wells shall be cleaned, tested, and produced in a manner to prevent pollution of the Lake h. Lessee shall employ procedures and use equipment that will eliminate or minimize any hazard of fire i. No production, processing, or any other type of wellhead equipment can be erected unless approved in writing by DER, USCG, and USCOE j. When and if the area is designated as a primary trawling area, the wellhead shall be fitted with a trawl deflector of approved design k. When and if the area is designated for other types of commercial fishing, the wellhead shall be fitted with a protective device of approved design l. Lessee shall mark each wellhead with a buoy marker of a design approved by DER and USCG and shall maintain such marker - each marker shall be identified with lessee's name and well number - a Department of Army permit from USCOE shall be obtained prior to installation m. A subsurface safety device approved by DER (automatic shut-in safety valve, tubing plug, or other safety device) shall be installed below the elevation of the lake bottom in all producing and shut-in wells to prevent escape of gas and other fluids in the event the well equipment is damaged (API Specifications 14A and 14B, October 1973)

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
36. Multiple completions	36a. It shall be unlawful to commingle the production of 2 or more gas strata prior to metering or measurement unless permitted by DEC b. Permission to commingle produced gas may be granted by DEC either administratively or after public hearing at DEC's discretion c. Upon DEC's request, any multiple completion must be tested as soon as feasible to demonstrate the effectiveness of production strata separation in witness of DEC or offset operators	36. Lessee shall not commingle the natural gas production from 2 or more reservoirs unless specific written permission for such commingling has been granted by DER
37. Production testing	37a. No gas except that produced during cleanup and testing may be emitted b. Cleanup and testing shall not exceed 72 hours without DEC permission c. Completed well must be flowed through a separator until all significant volumes of fracture fluids and connate saltwater are no longer produced d. After liquid-free flow has been established, absolute open-flow potential must be calculated through standard back-pressure testing e. Back-pressure or orifice-meter tests must be repeated annually unless required more frequently by DEC (offset operators shall be permitted to observe tests)	37a. During any period of testing following completion of a well or following well reworking, lessee shall maintain a record of production which shall be available to DER b. When a gas well has been completed, lessee shall determine the deliverability of the well according to recognized standards of back-pressure testing and shall report the observed field data to DER c. When lessee has caused a well test to be made, lessee shall submit the observed data to DER within 30 days d. At least once every 6 months, lessee will determine the open-flow potential of each producing well and will also take a 24-hour reservoir pressure test and will furnish to DER a copy of the results of all tests e. During reservoir pressure tests, shut-in pressures shall be taken with a deadweight gauge, after a minimum shut-in time period equal to the period required to reach stabilization or 24 hours, whichever is less

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
38. Pipelines	38a. All pipelines must be approved by DEC and other agencies with jurisdiction b. Pipelines must be pressure tested to 2000 psig or 200 psig in excess of anticipated working pressures, whichever is greater c. DEC reserves the right to grant pipeline rights-of-way across any state lands regardless of tract leasing arrangements d. The pipeline owner must supply DEC with a scaled map of the pipeline on the lakebed and immediate shore showing: - contributing wells - sizes and types of pipe - existing and proposed routes - locations of valves, separators, metering points, and protective coverings e. Sufficient check valves must be employed to prevent gas from one well entering another well with lower head pressure f. Pipelines must be inspected by a diver at least once per year and a report delivered to DEC within 30 days of inspection	38a. All gas produced for sales from leased premises shall be transported by pipeline to onshore locations in Pennsylvania and sold in U.S. markets b. Lessee is granted the right to lay pipelines at or below the lakebed for the sole purpose of removing gas from the lease block(s) c. All pipelines under shipping lanes and anchorages must be buried d. A route map must be submitted to DER's Division of Dams and Encroachments and to the USCG for approval and location permits 90 days prior to laying of pipes e. Lessee shall maintain a map or maps of its producing natural gas wells and collection systems and such map(s) shall be available for examination at all reasonable times by DER f. USCOE permit is required prior to laying pipes g. DER reserves the right to grant pipeline rights-of-way across any Pennsylvania lease blocks h. Before a pipeline may be used to transport any fluids not indigenous to Lake Erie, it must be pressure tested with water to twice anticipated working pressure i. DER must approve pipeline prior to operation j. Automatic shut-in safety valves actuated by pressure decline must be appropriately placed on all gathering lines k. All pipelines brought ashore must be buried below the wave base to avoid ice and storm damage
39. Saltwater disposal	39a. Connate saltwater produced with gas shall not be allowed to contaminate lake water b. Produced connate saltwater shall be stored at the point of separation in approved containers for appropriate land disposal c. No saltwater separator or collection device shall be installed at the wellhead or in submerged portions of the pipeline without DEC approval	

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
40. Accidental discharges	40a. Every reasonable precaution shall be taken to avoid spills or discharges of deleterious materials b. Contingency plans delineating procedures for responding to spills and accidental discharges shall be posted at all installations and vessels c. When a leak occurs, flow at a pipeline or installation shall be stopped as soon as possible while making repairs d. Operator must inform DEC by telephone and within 72 hours by letter of fires, breaks or leaks from which gas or fluids escape on any facility, installation, or vessel e. Within 72 hours of initial notification, operator shall file with DEC a detailed written report describing: - nature and amount of material spilled or discharged - probable cause - extent of operator's response - names of government agency personnel contacted - date and time contacted - status of contamination and cleanup program f. Follow-up reports must be submitted every 72 hours until pollution and endangerment of environment is abated	
41. Temporary abandonment	41. Upon demonstration of sufficient cause and written application, DEC may permit temporary removal of BOP from a well not yet completed provided that: - a casing string has been set and cemented to total depth - well has been tested for competency and capped at lake bottom - completion or permanent abandonment can be completed during the current drilling season - well site is marked with buoy - insurance and bonds are maintained	41a. Lessee shall not temporarily abandon any well without written permission from DER b. Permission for temporary abandonment may be granted by DER upon written application by lessee showing sufficiently good cause c. Upon termination of temporary abandonment period, lessee must either resume operations or permanently plug and abandon well

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
42. Permanent abandonment	42a. Uncompleted (nontemporarily abandoned) or depleted wells must be permanently plugged and abandoned after obtaining permission from DEC b. Verbal permission from DEC is sufficient for wells with valid drilling permit c. When permit to drill has expired, written notification 30 days prior to commencement of operations must be provided - transportation must be provided to DEC representative to witness operations - operator's contingency plan must be approved d. DEC representative may order any well plugged and abandoned if it is expected to cause environmental damage or an emergency exists e. Wells must be plugged with a cement slurry from total depth to lakebed by filling the wellbore from the bottom up f. Cement slurry must be water based, without aggregate, and have a density of 14.5 lb/gal	42a. If a well is found to be dry or nonproductive, it shall be plugged and abandoned b. Lessee shall give sufficient notice to DER of its intent to plug and abandon a well so that plugging operations may be witnessed c. Lessee shall have 6 months after termination, abandonment, or surrender in which to remove all machinery, well structures, equipment, pipelines, and other materials and drilling structures resulting from lessee's operations d. Lessee shall not be granted a final release from lease terms until an inspection of leased premises is completed by DER and USCOE and proper removal procedures are verified e. All wells shall be plugged by filling the hole completely with cement, including the inside and annulus of all casing left in the well f. Lessee shall plug all wells in a manner that: - ensures protection for potential gas-producing reservoirs - prevents the harmful infiltration of water into gas, water, or salt formations - constitutes no hazard to users of the surface - retains all fluids in their source formations - seals off reservoirs from those above and below g. No casing left in the well may extend above the lake bottom h. Lessee shall properly and effectively plug all wells on leased premises before abandoning, in accordance with regulations of Oil and Gas Division, DER, and all applicable laws of Pennsylvania i. A copy of plugging procedures approved by Oil and Gas Division shall be supplied to Minerals Section, Bureau of Forestry

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
42. Permanent abandonment (continued)		42j. Upon completion and plugging, a permanent marker of concrete or any other approved marker shall be erected over the well k. Marker shall extend from 10 ft below to 2 ft above lakebed and shall display the name of the drilling company and number of the well
43. Drilling log	43. Within 30 days after operations cease, a drilling log must be filed with DEC describing, in narrative form and chronological order, mechanical operations performed, strata lithologies penetrated, formation fluids encountered	43a. For operations performed during each 24-hour day, lessee shall keep a daily drilling record that is available to DER personnel at all reasonable times b. This drilling record shall contain all data usually acquired in normal drilling procedures including: - the depth at the beginning of the day or shift - the depth at the end of the day or shift - the diameter of the hole - any change in casing - if casing is set, all information regarding the setting--including size, type, grade and weight of casing, whether the casing is new or used, and the depth at which it is set - particulars of cementing - the depth at which any showing--however small--of oil, gas, or water is encountered; and the flows, pressures, and levels thereof - a report of each log, survey, formation test, deviation test, or other test taken or made - any suspension of operations - a description of drilling operations carried on, including fishing, shooting, perforating, acidizing, fracturing, surveying, and plugging

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
44. Drill cuttings	44. Within 30 days after drilling ceases, operator shall deliver to N.Y. Geologic Survey at operator's expense drill cuttings collected at 10-ft (or less) intervals from top of bedded rock to total depth	44a. If requested, lessee shall ship a complete set of samples to the Pennsylvania State Geological Survey within 30 days after completion of each well b. These samples must include: - samples of drill cuttings taken throughout the depth of the well from intervals of not more than 10 ft; such samples shall be washed, dried and bagged and accurately labeled by lessee with the name of the well and the depth interval - representative core chips from intervals of not more than 2 ft; such chips shall be washed, dried, and accurately labeled by lessee with the name of the well and the depth interval - the daily drilling records - if requested, samples of any oil, gas, or water recovered from any well c. When cores are taken, lessee shall pack them in numbered boxes accurately labeled showing the name of the well and the depth interval; the boxes shall be protected from damage and stored by lessee - no core shall be destroyed except for purpose of analysis - when cores are no longer required by lessee, they shall be forwarded to DER at lessee's expense - no person shall remove a core from Pennsylvania without written approval from DER d. When lessee has caused a core analysis or any other analysis to be made, lessee shall submit a copy thereof to DER within 30 days
45. Well logs	45. Copies of well logs shall be sent to DEC within 30 days from when they were run	45. When any log or survey is taken, 2 final copies shall be supplied to DER within 30 days

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
46. Completion records	46. Within 30 days of completion or abandonment, operator shall submit to DEC a completion report describing - mechanical aspects of drilling, casing, cementing, conditioning, fracturing, stimulating, plugging - diagrammatic sketch of any multiple completions - written resumé of procedures and equipment effecting separation of contributing reservoirs	46a. Within 30 days after completion of each well, lessee shall furnish DER an accurate location plot, a detailed lithologic log, a detailed history of the well, and all well data including geologic, driller, electrical, and any other well surveys made to obtain subsurface information b. Lessee shall furnish the following to DER within 30 days after the end of boring, drilling, or deepening operations: - a copy of all drill-stem test reports and a copy of the pressure charts for each drill-stem test taken at the well - a list of the drill-stem tests taken at the well, indicating the chronological sequence and depth interval of each drill-stem test
47. Plugging report	47. Within 30 days of abandonment, a report signed by DEC representative and/or a diver observing the operation must be filed with DEC	47. When a well is reworked, stimulated, plugged-back, or recased, lessee shall notify DER within 30 days
48. Confidentiality	48. The above information may be requested to be kept for only confidential DEC and State Geologic Survey use until one year after well completion	48. Well information obtained from lessee and recorded with DER shall be confidential for 1 year from well completion except when lessee consents in writing to its release at an earlier date, and except the following information which shall not be held confidential: applications and submissions at public hearings; monthly and annual production data; wastewater disposal data for individual wells or systems
49. Purchase reports	49. All purchasers, transporters, or takers of gas shall file at least annually a report with DEC reflecting amount purchased, transported, or taken	49a. Lessee shall submit statements by individual wells of production and sales of gas on the 25th day of each calendar month covering preceding month's production b. Provision of all well data required by DER by lessee under lease terms does not relieve lessee of its responsibility to provide identical well data to other agencies within DER or to other state or federal government agencies where such data are required to be submitted by law

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
49. Purchase reports (continued)		49c. Lessee shall furnish to DER, on request, meter charts covering the production of each well on the lease d. Meter charts may be kept for examination for a period not to exceed 90 days e. Lessee shall furnish or secure for DER any statements furnished to lessee by any person or agency to whom lessee delivers for sale or transport any oil, gas, or other products produced from leased premises f. Lessee must authorize and direct any entity to whom it sells or furnishes natural gas produced from any well covered by the lease to disclose and exhibit accounts and other instruments to DER, upon request, having to do with transactions involving payments to lessee for natural gas from wells covered by the lease
50. Contingency plan	50. As part of an application for a permit to drill, operator must file a contingency plan with DEC delineating procedures that would be instigated in response to a spill or accidental discharge of deleterious material to include: - instructions for immediate corrective action by company representative - internal alert plan to notify company personnel - assignment of corporate responsibility for direction and supervision of company's containment and cleanup effort and cooperation with government agencies - external alert plan for systematic and immediate notification by telephone of DEC, USCG, USCOE, executives of all municipalities maintaining public water supply intakes within a radius of 3 miles of discharge	

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
51. Gas measurement		51a. All gas-producing wells shall be equipped with adequate facilities for continuously metering gas b. DER may permit group meter measurements c. Meter charts and relevant records shall be kept on file and made available to DER on request d. Volume of gas produced, saved, and marketed shall be measured according to Boyle's Law: - unit volume is 1 ft^3 at 60°F and 14.73 psi - average absolute atmospheric pressure is 14.4 psi - arithmetic average temperature recorded each 24-hour day will be used in computing gas volumes or otherwise assumed to be 50°F - specific gravity shall be determined by Edwards or Acme gravity balance at intervals of 3 months - apparatus and method shall be in accordance with National Bureau of Standards or Report No. 3 of Gas Measurement Committee of American Gas Association
52. Deviated drilling		52a. The wellbore may not vary unreasonably from the vertical at depth b. Amount of deviation must be measured by lessee every 500 ft c. If DER determines that the wellbore has been excessively deviated, DER may require lessee to have the wellbore surveyed d. DER may require a wellbore with unreasonable location and spacing violations to be re-drilled, or plugged and abandoned e. Lessee may conduct directional drilling with DER approval if there is no encroachment onto adjoining leaseholds or drilling units; application must include a description of well number, bottom hole location, reason for deviation, and names of adjacent lease holders f. A complete angular deviation and directional survey performed by a survey company must be submitted to DER

Table A.1. Continued

Component of Proposed State Lease or Operational Rules and Regulations Addressed by New York and Pennsylvania	New York	Pennsylvania
53. Safety precautions for H_2S		53a. Lessee shall take all safety precautions necessary to prevent uncontrolled escape of H_2S gas from wells and facilities b. Lessee shall install adequate emergency shut-down equipment, H_2S gas-detection and monitoring equipment, hazardous-condition alarms, and personnel-safety equipment, particularly protective breathing apparatus at all facilities where H_2S gas in concentrations exceeding 100 ppm is anticipated or used c. Lessee shall make gas masks and portable H_2S gas detectors readily available for use at all sites, particularly drill sites where H_2S gas is anticipated or used d. After H_2S has been initially detected by any device, lessee shall conduct frequent checks of all areas of poor ventilation with a portable H_2S detector e. Lessee shall use special steel pipe and casing which is resistant to H_2S stress cracking in wells and facilities handling the gas in concentrations exceeding 100 ppm f. Lessee shall quickly notify and evacuate, if necessary, all persons in the vicinity if dangerous quantities of H_2S gas uncontrollably escape from oil or gas facilities g. Lessee shall post warning signs around all well sites or other facilities handling toxic H_2S gas in concentrations exceeding 100 ppm; the warning signs should be visible on all approaches to and at a safe distance from all facilities handling the H_2S gas, including warning markers on all pipelines which may be used to transmit the toxic gas h. Lessee shall immediately notify DER and record on appropriate well records and driller's logs any H_2S gas found in the course of drilling or producing operations

[a]Sources: New York State Department of Environmental Conservation, "Development of Natural Gas Reserves Beneath the New York State Portion of Lake Erie: A Report to the New York State Legislature," February 1, 1977; Commonwealth of Pennsylvania Department of Environmental Resources, "Natural Gas Lease for the Lands Beneath Lake Erie Within the Jurisdiction of the Commonwealth of Pennsylvania," revised August 1977.

Abbreviations: DEC = Department of Environmental Conservation; DER = Department of Environmental Resources; USCG = U.S. Coast Guard; USCOE = U.S. Army Corps of Engineers; API = American Petroleum Institute.

APPENDIX B. FACT SHEETS DESCRIBING EQUIPMENT, COSTS, AND PERSONNEL REQUIRED FOR REFERENCE PROGRAM RIGS, VESSELS, AND FACILITIES

Table B.1. Equipment, Costs, and Personnel for the U.S. Lake Erie Reference Program Seismic Survey Vessel

Vessel Engineering Specifications	
Hull	
Length	165 ft
Width	48 ft
Draft	10 ft
Registered tonnage	52 tons
Mobility	Two 400-hp diesel engines with twin screw propellers
Seismic survey equipment	
Energy source	Air gun
Reflected energy gathering equipment	6 traces of 48 hydrophones, each measuring 50 m
Material inventory	
Diesel fuel	100,000 gal
Sewage waste holding tank	15,000 gal
Economics	
Capital Cost	
Vessel	$5,000,000
Survey equipment	$2,500,000
Daily rental rate (includes harbor cost)	$ 15,000
Personnel	
Boat crew	4
Seismic crew	10
Manager	1
Observers	4
Mechanics	2
Cable hands	2
Utility hands	2
Total	25

Table B.2. Equipment, Costs, and Personnel for the U.S. Lake Erie Reference Program Jack-up Rig

Rig Engineering Specifications	
Hull	
Length	100 ft
Width	70 ft
Depth	15 ft
Draft (legs lifted)	15 ft
Registered tonnage	500 tons
Water depth capability	
75 ft	12-ft air gap, 15-ft muds
60 ft	12-ft air gap, 30-ft muds
Mobility	Rig will have no propulsion engines; must be towed by service tugs
Legs	
Length	120 ft
Diameter	42 in.
Number	4 per rig
Footings	Each leg will be supported by a 20-ft square, 8-ft high pad equipped with a high-pressure water jet system for recovery from mud
Material inventory	
$CaCl_2$	600 sacks
Bentonite	100 sacks
Cement	600 sacks
Polymer	100 sacks
Additives	100 sacks
Diesel fuel	16,000 gal
Liquid mud storage	Three 100-bbl tanks
Power plants (diesel-electric system)	Two 700-hp diesel engines (one used for backup only) powering two 600-kW, 3-phase, 60-cycle, 600-V alternators
Crane	One 25-ton capacity, 60-ft boom crane
Other equipment	Eating and sleeping accommodations for 25 persons 15,000-gal sewage holding tank Water-treatment plant Fire-fighting equipment Personnel basket Air compressor Decompression chamber Helicopter landing pad Provisions for storage and transfer of spent drilling fluids, sewage waste, garbage, and drill cuttings

Table B.2. Continued

Drilling Equipment	
Drill string	
Kelly	3-1/2 in. × 40 ft, square
Drill pipe	5000 ft long, 3-1/2 in. wide, 13.3 ppf, grade E
Drill collars	22; 5-5/8 in. × 2-1/2 in. × 30 ft
Mast	100 ft, 400,000-lb capacity
Substructure	20 ft, 400,000-lb casing capacity, 400,000-lb setback capacity
Drawworks	Sufficient to lift 500,000 lb; driven by a suitable electric motor
Rotary table	17 in. minimum diameter
Traveling equipment	4-sheave block with 1-1/8-in. line (or larger); 200-ton capacity hook and swivel
Rig pumps	2 triplex pumps with 6-in. bore, 8-in. stroke (or similar pumping capacity); powered by electric motor 1 auxillary triplex pump with 5-in. bore, 7-in. stroke
Blowout prevention equipment (all components are Series 900 [3000 psig], H_2S trim)	One 10-in. rotating head One 8-in. annular preventer One 8-in. pipe and blind ram blowout preventer One 40-gal accumulator (3-in. OD, 3000 psig)
Solids control	One 48-in. shale shaker, with 80-mesh screen Desander Desilter (removal of particles > 10 μm)
Cement system	High-pressure jet system
Economics	
Capital cost	$6,000,000
Daily rental rate (includes harbor cost and service vessel fee)	$ 13,600

Table B.2. Continued

Personnel		
Two full crews aboard and one crew on shore leave	On Duty	Aboard Rig
Tool pushers	1	2
Drillers	1	3
Derrickmen	1	3
Floormen	3	6
Mechanics	1	2
Crane operators	1	2
Kitchen help	2	3
Geologists, company representatives, inspectors, etc.	2	4
Total	12	25

Table B.3. Equipment, Costs, and Personnel for the U.S. Lake Erie Reference Program Floating Rig

Rig Engineering Specifications	
Hull	
Length	260 ft
Width	44 ft
Depth	22 ft
Draft	10 ft (loaded)
Registered tonnage	1850 tons
Water depth capability	200 ft plus
Mobility	Rig will have no propulsion engines; must be towed by service tugs
Positioning system	Rig will have one bow thruster and one stern thruster powered by electric motors Rig will be stabilized in position, using ten 9000-lb anchors off five 1-1/8-in. cables (two anchors on one cable) Anchors are set in place with the aid of a service tug
Material inventory	
$CaCl_2$	600 sacks
Bentonite	100 sacks
Cement	600 sacks
Polymer	600 sacks
Additives	100 sacks
Diesel fuel	16,000 gal
Liquid mud storage	Three 100-bbl tanks
Power plants (diesel-electric system)	Two 700-hp diesel engines (one used for backup only) powering two 600-kW, 3-phase, 60-cycle, 600-V alternators
Crane	Two cranes, each with 25-ton capacity, 60-ft boom
Other equipment	Eating and sleeping accommodations for 25 persons 15,000-gal sewage holding tank Water-treatment plant Fire-fighting equipment Personnel basket Air compressor Decompression chamber Helicopter landing pad Provisions for storage and transfer of spent drilling fluids, sewage waste, garbage, and drill cuttings

Drilling Equipment	
Drill string	
Kelly	3-1/2 in. × 40 ft, square
Drill pipe	5000 ft long, 3-1/2 in. wide, 13.3 ppf, grade E
Drill collars	22; 5-5/8 in. × 2-1/2 in. × 30 ft 4; 8 in. × 2-1/2 in. × 30 ft
Mast	100 ft, 400,000-lb capacity
Substructure	20 ft, 400,000-lb casing capacity, 400,000-lb setback capacity
Drawworks	Sufficient to lift 500,000 lb; driven by suitable electric motor
Rotary table	17 ft minimum diameter
Traveling equipment	4-sheave block with 1-1/8 in. line (or larger); 200-ton capacity hook and swivel
Rig pumps	2 triplex pumps with 6-in. bore, 8-in. stroke (or similar pumping capacity); powered by electric motor 1 auxiliary triplex pump with 5-in. bore, 7-in. stroke
Blowout prevention equipment (all components are Series 9000 [3000 psig], H_2S trim)	One 10-in. rotating head One 8-in. annular preventer One 8-in. pipe and blind ram blowout preventer One 40-gal accumulator (3-in. OD, 3000 psi)
Solids control	One 48-in. shale shaker, with 80-mesh screen Desander Desilter (removal of particles > 10 μm)
Cement system	High-pressure jet system
Economics	
Capital cost	$7,000,000
Daily rental rate (includes harbor cost and service vessel fee)	$ 16,800

Table B.3. Continued

Personnel Two full crews aboard and one crew on shore leave	On Duty	Aboard Rig
Tool pushers	1	2
Drillers	1	3
Derrickmen	1	3
Floormen	3	6
Mechanics	1	2
Crane operators	1	2
Kitchen help	2	3
Geologists, company representatives, inspectors, etc.	2	4
Total	12	25

Table B.4. Equipment, Costs, and Personnel for the U.S. Lake Erie Reference Program Stimulation Barge and Service Vessel

Barge Engineering Specifications	
Hull	
Length	200 ft
Width	40 ft
Depth	8 ft
Draft	8 ft
Mobility	Barge will have no propulsion engines; must be towed by service tugs
Material inventory (sufficient to stimulate three wells)	
Hydrochloric acid (15%)	1,500 gal
Sand	114,000 lb
Surfactant	75 gal
$CaCl_2$	7,500 lb
Bentonite	2,400 lb
CO_2 or N_2	600,000 CF
Diesel fuel	2,000 gal
High-pressure injection system	4 triplex pumps with 6-in. bore, 8-in. stroke (powered by diesel engines capable of pumping 40-55 bbl/min at 3000 psig)
Stimulation returns separation and storage system	Gas-liquid separator Three 20,000-gal liquid storage tanks
Power plants	Four 750-hp diesel engines
Economics	
Capital cost	$500,000
Daily rental rate (includes harbor cost and service vessel fee)	$ 4,500
Personnel	
Crew members	5-8

Table B.4. Continued

Vessel[a] Engineering Specifications	
Hull	
Length	96 ft
Width	28 ft
Draft	6 ft
Registered tonnage	30 tons
Mobility	Two 300-hp diesel engines with twin screw propellers
Material inventory (while in transit to rig)	
Supplies for rig	
$CaCl_2$	300 sacks
Cement	300 sacks
Polymer	50 sacks
Additives	50 sacks
Diesel fuel	5000 gal (2000 for vessel, 3000 for transfer to rig)
Wastes from rig	
Sewage	7,500 gal
Drill cuttings	25 tons
Garbage	200 lb
Spent drilling fluids	12,600 gal
Spent oily wastes	55 gal
Passenger capacity	12
Economics	
Capital cost	$600,000
Daily rental rate (includes harbor cost)	$ 3,000
Personnel	
Captain	1
Deck hands	2
Total	3

[a]Accompanied by small barge.

Table B.5. Equipment, Costs, and Personnel for the U.S. Lake Erie Reference Program Underwater Pipeline System[a]

	Clinton-Medina	Lockport
Pipeline Engineering Specifications		
Field collection area	25 mi^2	25 mi^2
Number of wells serviced	25 @ 640-acre well spacing	50 @ 320-acre well spacing
Maximum anticipated flow per well	300 MCFD	950 MCFD
Average anticipated flow per well (Year 1)	155 MCFD	670 MCFD
Maximum anticipated flowing pressure at wellhead	450 psia	800 psia
Gathering lines	20 mi of 2-in. pipe	30 mi of 2-in. pipe
Trunk line	4 mi of 6-in. pipe	9 mi of 6-in. pipe
Flowline to shore	One per 25-well field (5, 10, or 20 mi of 6-in. pipe)	Two per 50-well field (5, 10, or 20 mi of 8-in. pipe)
Valving system	One 2-in. wing valve per well One 2-in. backflow check valve per well One 6-in. safety valve per field	One 2-in. wing valve per well One 2-in. backflow check valve per well Two 6-in. safety valves per field
Lowest line pressure anticipated in line	75 psia	128 psia
Onshore line pressure standards		
Transmission	200 psia	200 psia
Distribution	60 psia	60 psia
Method of securement to lakebed	Burial of pipes in <30 ft of water (5-10 ft deep) Screw-anchor pipes in consolidated sediments in water depths greater than 30 ft	Burial of pipes in <30 ft of water (5-10 ft deep) Screw-anchor pipes in consolidated sediments in water depths greater than 30 ft
Optional Glycol Injection Lines[b]		
Dispensing lines	20 mi of 1/2-in. pipe	30 mi of 1/2-in. pipe
Trunk line	4 mi of 1-in. pipe	4.5 mi of 1-in. pipe
Feeder line	One per 25-well field (5, 10, or 20 mi of 1-in. pipe)	One per 25-well field (5, 10, or 20 mi of 1-in. pipe)
Quantity of glycol in system (including dispensing, trunk, and feeder lines)		
5-mi feeder line	2,800 gal	5,300 gal
10-mi feeder line	3,800 gal	7,300 gal
20-mi feeder line	5,800 gal	11,300 gal
Method of securement to lakebed	Installed and bundled together with gas flowlines	Installed and bundled together with gas flowlines
Economics		
Capital cost of installed gas collection system (including gathering, trunk, and flow lines)		
5-mi flowline	$ 912,000	$1,907,000
10-mi flowline	$1,211,000	$2,715,000
20-mi flowline	$1,807,000	$4,331,000
Capital cost of installed glycol injection system (including dispensing, trunk, and feeder lines and glycol for line flooding)		
5-mi feeder line	$254,500	$436,600
10-mi feeder line	$304,500	$536,400
20-mi feeder line	$404,000	$735,800

[a] See Figures B.1 and B.2.

[b] Installed with gas collection system and brought on-line when inhibition of hydrate formation is made necessary by significant decrease in gas flow to shore. Glycol is injected into gas stream at wellhead and recovered onshore.

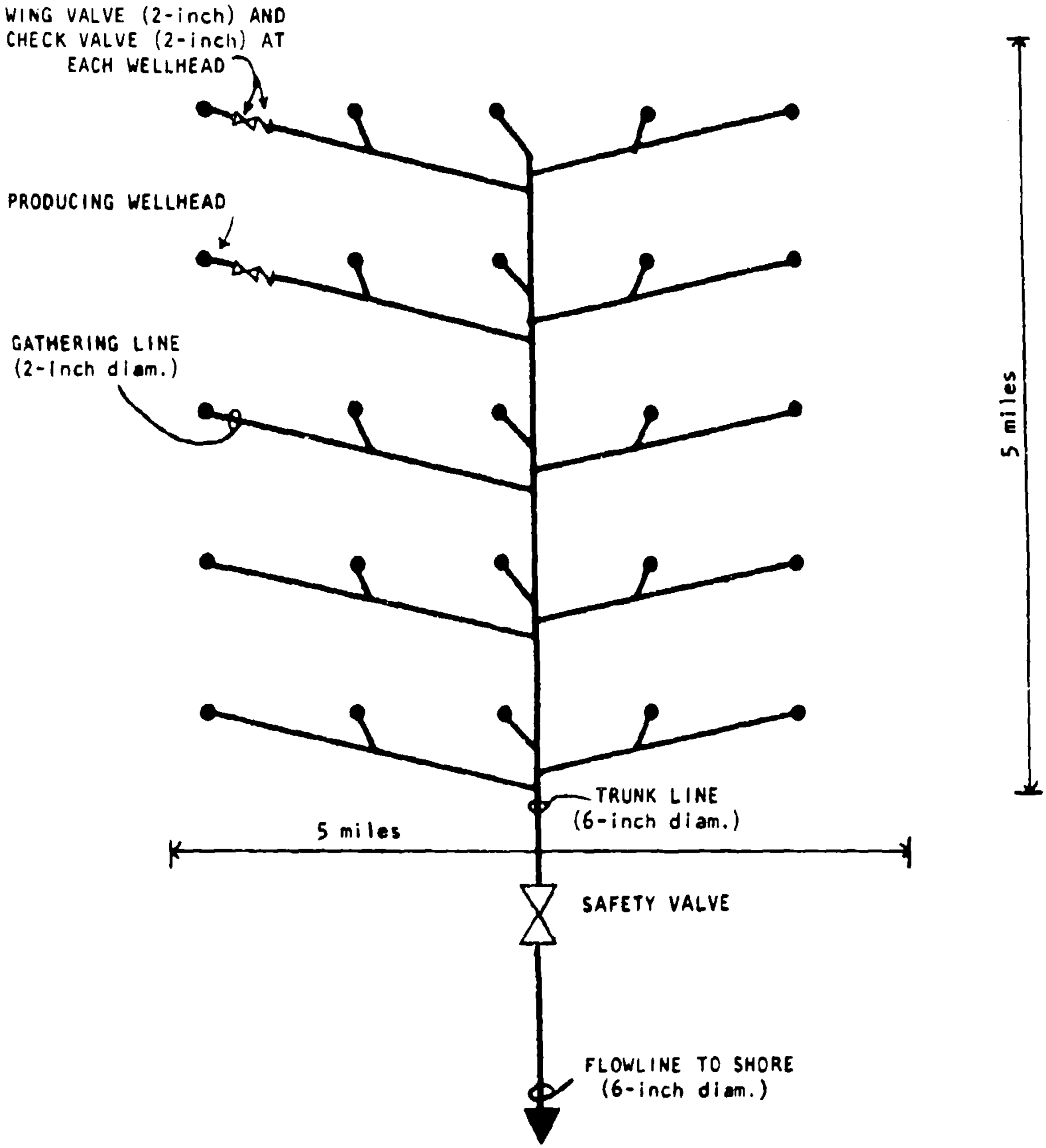

Figure B.1. Clinton-Medina Underwater Natural Gas Pipeline System. The system collects and pipes gas to shore from a field of 25 wells (each draining 640 acres of land) distributed over an area of 25 mi^2.

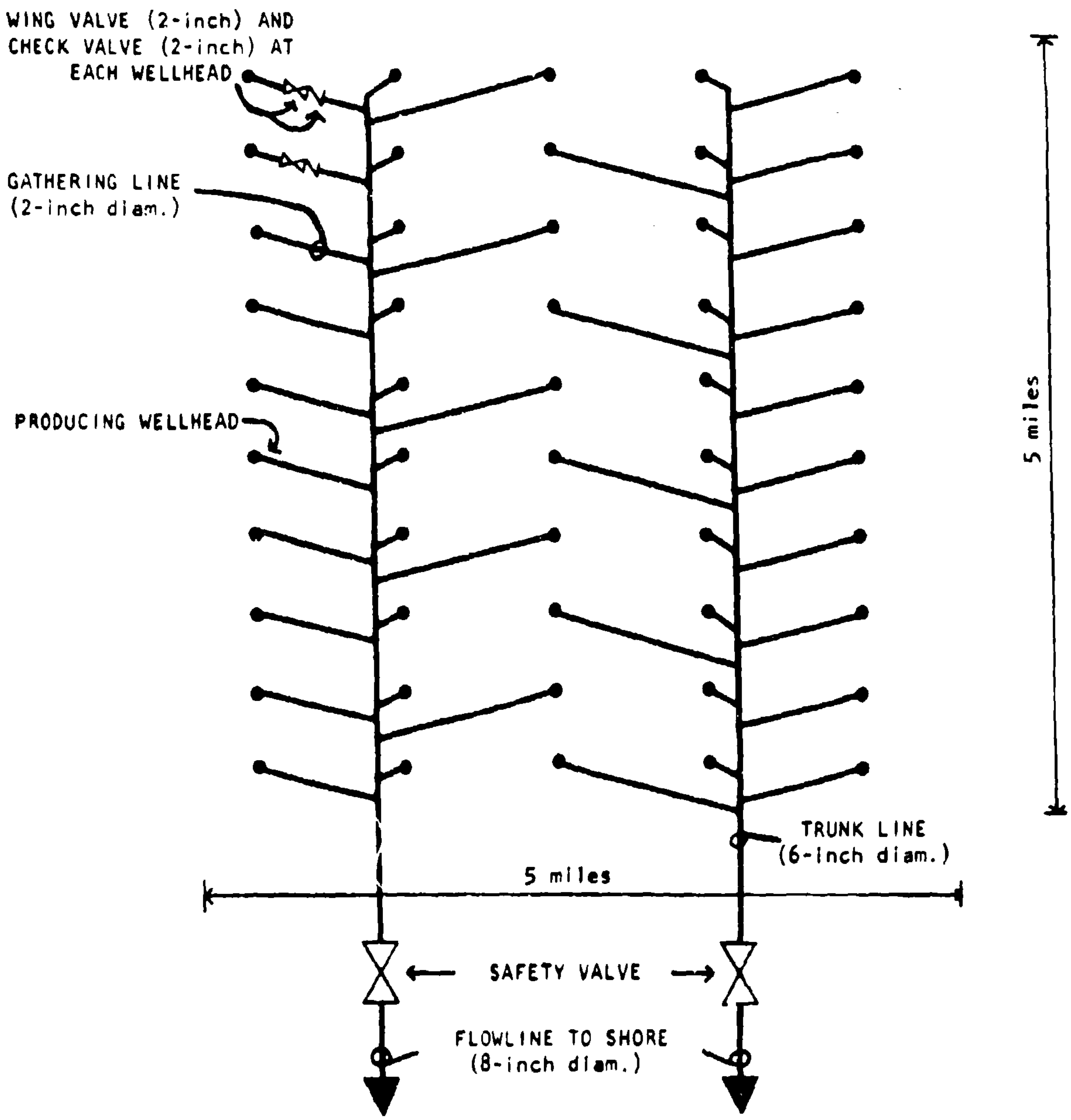

Figure B.2. Lockport Underwater Natural Gas Pipeline System. The system collects and pipes gas to shore from a field of 50 wells (each draining 320 acres of land) distributed over an area of 25 mi^2.

Table B.6. Equipment, Costs, and Personnel for the U.S. Lake Erie Reference Program Gas Process Plant[a]

Plant Engineering Specifications	
Plant functions	Remove liquid water and water vapor from gas stream and increase gas line pressure to distribution line standards
Optional plant functions (constructed and/or operated if conditions warrant)	Inject glycol into underwater wellheads to inhibit hydrate formation; recover and regenerate glycol onshore; separate and store condensate from gas stream
Plant equipment	Free water knock-out system Produced formation water storage tanks Glycol dehydration unit Condensed water (from glycol reboiler) storage tank Gas stream compressor unit Gas metering unit State-of-the-art safety equipment Optional glycol injection and recovery system Optional condensate separation and storage system (see Figure B.4)
Plant siting criteria	The plant should be located between a pipeline landfall and the nearest onland distribution/transmission line: 0.5 mi from landfall; 0.5 mi from distribution/transmission line
Land requirements	3 acres for buildings, storage area, parking area, and buffer zone 30-ft rights-of-way for pipes coming into and exiting from the plant
Residuals, Emissions, Discharges, and Wastes	
Noise[a]	80-100 decibels at source from continued operation of compressors and boilers; >100 decibels at source during annual short-term venting of pipelines
Liquid wastes	Saline formation water contaminated with some lightweight liquid hydrocarbons Condensed water vapor from glycol reboiler contaminated with some lightweight liquid hydrocarbons

Table B.6. Continued

Solid wastes[a]	Equipment cleaning rags Waste paper and paper cartons Spent cartridges from water coalescers and glycol, oil, and fuel filters Floor cleaning compounds, oil absorbents, and equipment cleaners Scrap metal from equipment repairs Nonreturnable chemical and lubricating oil drums
Atmospheric emissions	Routine leakage of small amounts of hydrocarbons from valves and fittings Combustion by-products from compressor engines and industrial boilers (particulates, sulfur oxides, carbon monoxide, hydrocarbons, nitrogen oxides)
<u>Economics</u>	
Capital cost of installed compressor	
Facilities servicing Clinton-Medina reservoirs	\$24,000/MMCFD of gas produced
Capital cost of installed dehydrator and adjunct equipment (free water knockout system, water storage tank, valves and fittings, safety equipment)	\$5670/MMCFD of gas produced plus \$50,000 base cost
Capital cost of glycol injection facility (does not include installation)	\$4000-\$5600/MMCFD of gas produced (depending on total volume of gas processed)
Operation and maintenance costs	
Facilities servicing Clinton-Medina reservoirs	\$0.28/MCFD of gas produced
<u>Personnel</u>	Unmanned facility with daily inspections by one or two company employees Monthly removal of stored wastewater and solid wastes by private waste management firm Periodic machinery maintenance by two company mechanics

[a]See Figure B.3.

[b]Source: New England River Basin Commission (1978).

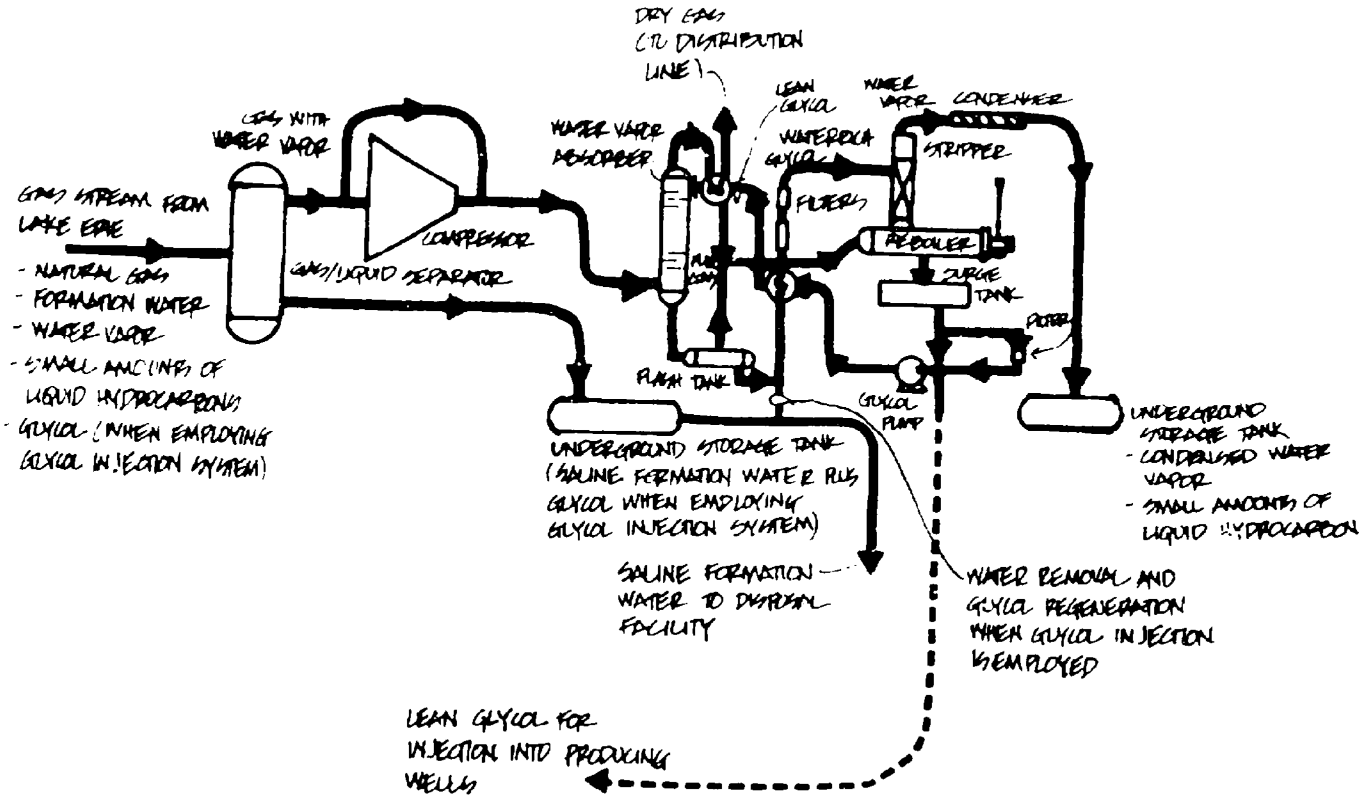

Figure B.3. Reference Program Gas Process Plant

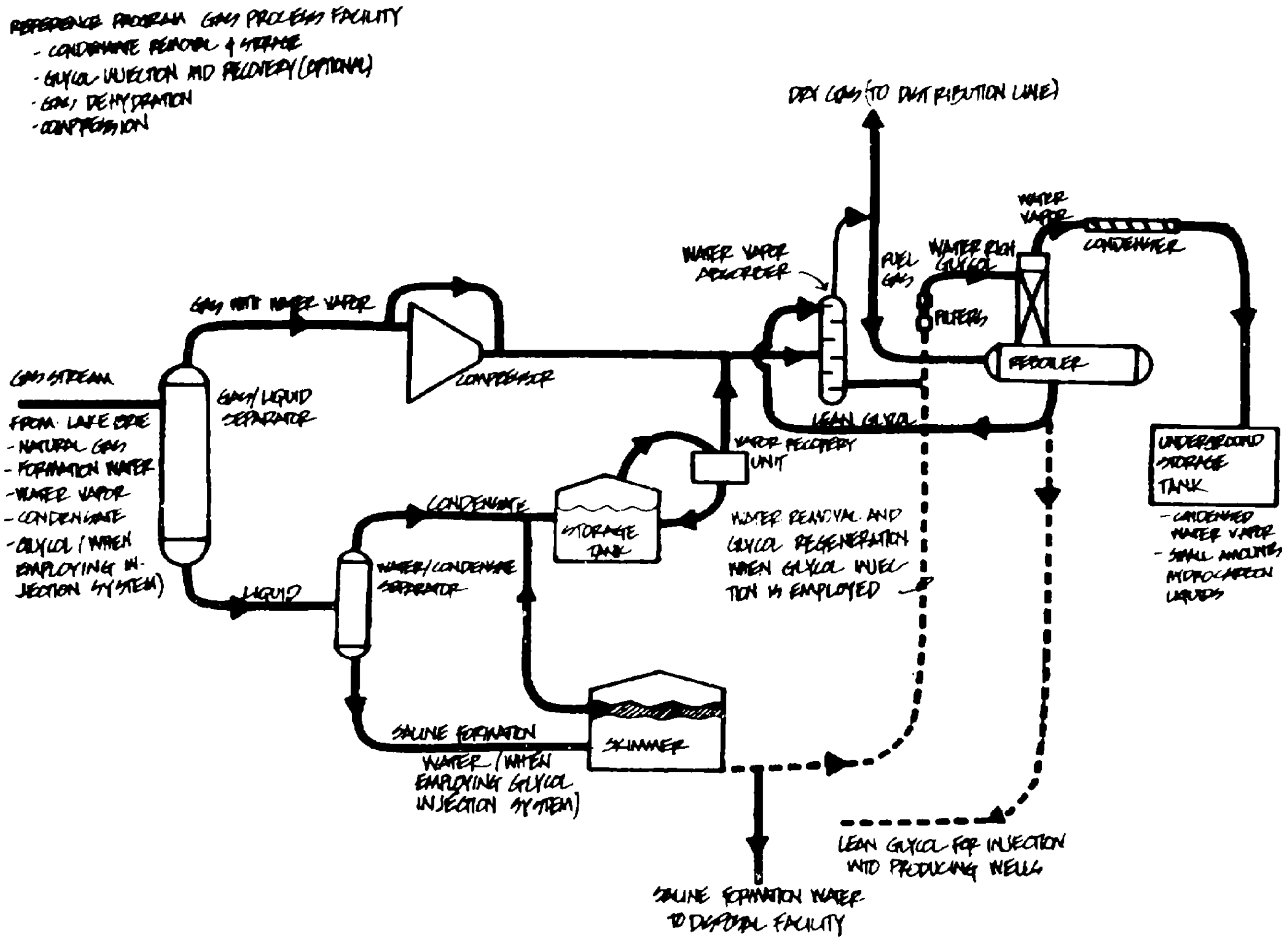

Figure B.4. Reference Program Gas Process Plant with Optional Condensate Separation and Storage System. Water vapor absorber and reboiler are not drawn in detail; refer to Figure B.3 for more detailed information on ma' -ial flow.

Table B.7. Equipment, Costs, and Personnel for the U.S. Lake Erie Reference Program Gas Treatment Plant[a]

Plant Engineering Specifications	
Plant functions	Remove liquid water and water vapor from gas stream, increase gas line pressures to distribution line standards, and remove H_2S from gas stream
Optional plant functions (constructed and/or operated if conditions warrant)	Inject glycol into underwater wellheads to inhibit hydrate formation; recover and regenerate glycol onshore; separate and store condensate from gas stream
Plant equipment	Free water knock-out system Produced formation water storage tanks Glycol dehydration unit Condensed water (from glycol reboiler) storage tank Gas stream compressor unit Gas metering unit State-of-the-art safety equipment Methyl ethyl amine (MEA) unit for H_2S removal Claus elemental sulfur recovery unit Shell Claus Offgas Treater to lower SO_2 emissions Optional glycol injection and recovery system Optional condensate separation and storage system (see Fig. B.4)
Plant siting criteria	The plant should be located between a pipeline landfall and the nearest onland distribution/transmission line: 0.5 mi from landfall; 0.5 mi from distribution/transmission line
Land requirements	3-10 acres for buildings, storage area, parking area, and buffer zone 30-ft rights-of-way for pipes coming into and exiting from the plant
Residuals, Emissions, Discharges, and Wastes	
Noise[b]	80-100 decibels at source from continuous operation of compressors, boilers, scrubbers, and flarestacks; >100 decibels at source during annual short-term venting of pipelines

Table B.7. Continued

Liquid wastes	Saline formation water contaminated with some lightweight liquid hydrocarbons Condensed water vapor from glycol reboiler contaminated with some lightweight hydrocarbons Cooling water wastes contaminated with antiscaling and anticorrosion agents (sulfuric acid, chromium, zinc, chlorine)[a] Boiler water wastes contaminated with antiscaling and anticorrosion agents (phosphates, bases, sulfite, and sludge conditioners (e.g., phosphates, tannins, lignins, starch, etc.)[a]
Solid wastes[b]	Equipment cleaning rags Waste paper and paper cartons Spent cartridges from water coalescers and glycol, oil, and fuel filters Floor cleaning compounds, oil absorbents, and equipment cleaners Scrap metal from equipment repair Nonreturnable chemical and lubricating oil drums Spent "iron sponge" (iron dioxide and wood chips) material used to sweeten sour gas streams Scale and sludge from boiler cleanout Scale and sludge from cooling-tower cleanouts Tank cleaning sludge (oily wastes, solids, and scale) Filtration media such as diatomaceous earth, sand, gravel, and other filter bed material Plastic and rubber wastes (packaging gaskets and filter material) Spent sieve material Contaminated sulfur Contaminated catalyst Residuals from chrome reduction and precipitation from cooling water by ferrous sulfate or other reducing agent if used

Table B.7. Continued

Atmospheric emissions	Routine leakage of small amounts of hydrocarbons and hydrogen sulfide (H_2S) from valves and fittings SO_2 emissions from H_2S removal system (Shell Claus Offgas Treater) Combustion by-products from compressor engines and industrial boilers (particulates, sulfur oxides, carbon monoxide, hydrocarbons, nitrogen oxides) Steam emissions from Claus sulfur recovery unit
<u>Economics</u>	
Capital cost of installed compressor	
Facilities servicing Lockport-Guelph reservoirs	$14,000/MMCFD of gas produced
Capital cost of installed dehydrator and adjunct equipment (free water knockout system, water storage tank, valves and fittings, safety equipment)	$5670/MMCFD of gas produced plus $50,000 base cost
Capital cost of installed H_2S removal, elemental sulfur recovery, and SO_2 emission reduction systems	$114,286/MMCFD of gas produced plus $91,000 royalty payment for Shell Claus Offgas Treater
Capital cost of glycol injection facility (does not include installation)	$2800-3040/MMCFD of gas produced (depending on total volume of gas processed)
Operation and maintenance costs	
Facilities servicing Lockport reservoirs	$0.21/MCFD of gas produced
<u>Personnel</u>	Continuous operation and maintenance by 5-10 employees, depending on the size of the plant Monthly removal of stored wastewater, solid wastes, and sulfur by private waste management firms

[a] See Figure B.5.

[b] Source: New England River Basin Commission (1978).

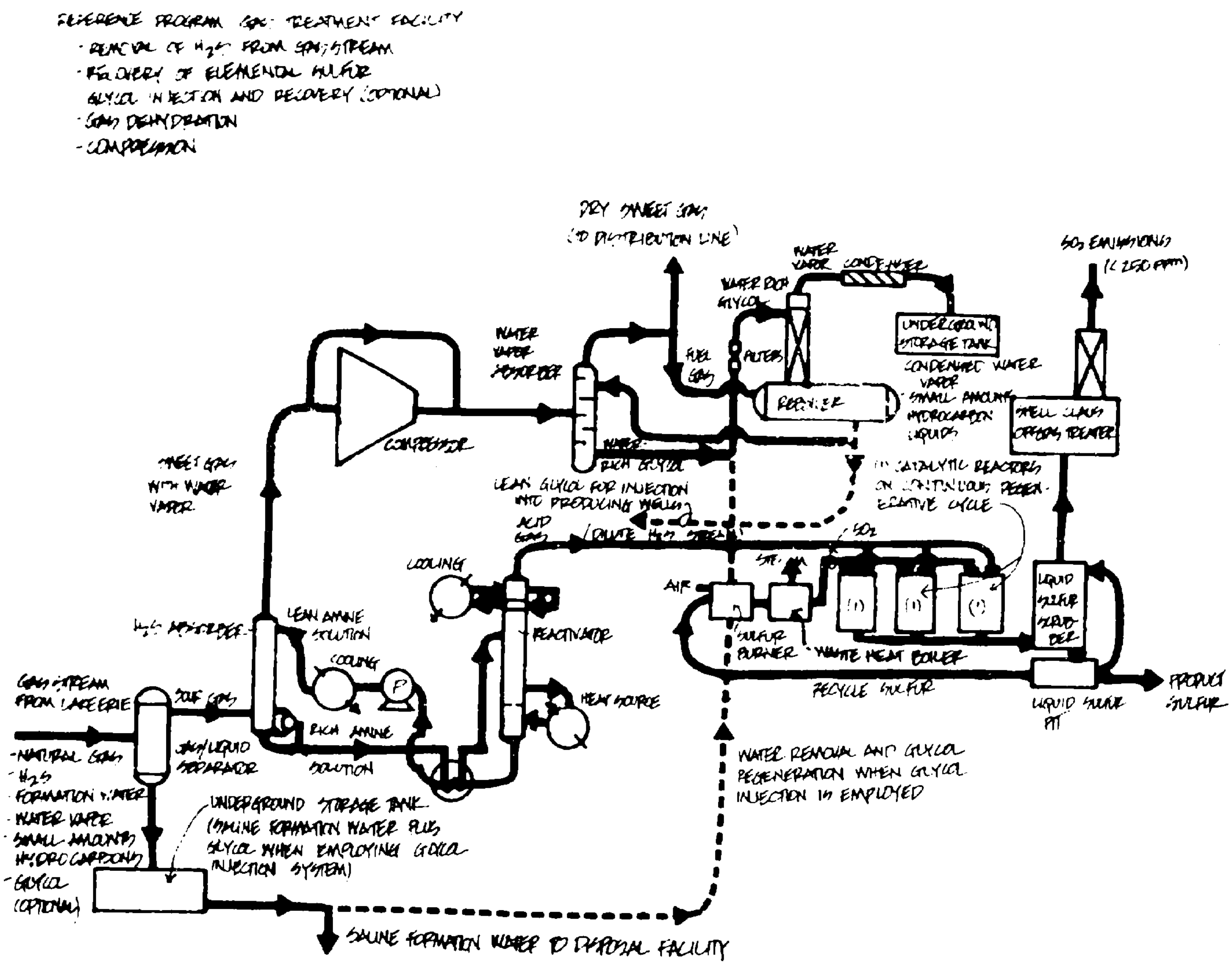

Figure B.5. Reference Program Gas Treatment Plant.

APPENDIX C. ACCIDENT ASSUMPTIONS USED FOR MODELING DISCHARGES OF MATERIALS AND RESIDUALS TO THE LAKE

INTRODUCTION

C.001

Four scenarios describing potential accidents during the exploration, development, and production phases of the Reference Program are outlined in this appendix.

C.002

Since there are insufficient data to permit accurate estimation of the probability that any of these accidents will occur during the Reference Program and since the probabilities depend upon the specifics of the assumed accident, no such probability estimates were made. Rather, relative probabilities are indicated in general terms for each of the categories. In particular, the first scenario--an oil blowout on an exploratory well--is considered to be an event with an extremely small probability of occurrence and is therefore assigned a special frequency category. The anticipated consequences of such an unlikely occurrence are described because of the perceived public concern over such an event on Lake Erie, should drilling be permitted.

C.003

In view of the large number of materials that could be accidentally released, in-lake concentration estimates were made only for those materials that were judged to have some potential for negatively impacting the aquatic environment, and/or that have aroused public concern. In some cases, it was possible, using turbulent diffusion theory, to estimate concentrations near the point of release and to calculate concentrations at a distance of 0.5 mile from the release (closest allowed approach to a water intake). Because of the wide range of environmental and other conditions possible at the time of release, these concentrations could only be estimated. Because of these uncertainties, the assumptions upon which the calculations are based were chosen so as to give worst-case estimates.

POTENTIAL ACCIDENTS USED FOR MODELING DISCHARGES OF MATERIALS AND RESIDUALS TO THE LAKE (see also Table 1-35)

C.004

1. Exploratory Well Oil Blowout (Special Frequency Category)

    a. Accident Assumptions

        (1) Reservoir is geopressurized significantly above anticipated static bottom hole pressure of 2000 psia.

(2) Reservoir contains liquid hydrocarbons (39° API).

(3) Reservoir conditions (porosity, permeability, specific gravity, viscosity) allow flow of liquid hydrocarbons out of host formation and up wellbore.

(4) Well is drilled into Ordovician and/or Cambrian rocks where the drill bit encounters a geopressurized, liquid-bearing formation.

(5) Mud weight is not sufficient to control flow of liquids into the wellbore.

(6) All BOP equipment--i.e., hydril, pipe rams, blind rams--fail to operate.

(7) Liquids conducted up the wellbore displace drilling fluids to the mud tanks; mud tanks eventually overflow.

(8) Gases are separated from liquids at the rig deck and vented or flared to the atmosphere.

(9) If reservoir pressures are high enough to fracture confining wellbore formations or the cement bond around any casing string, liquids could be forced outside of the wellbore; under worst-case conditions, formation fractures could conduct liquids upward resulting in direct displacement of all fluids to the Lake at the sediment/water interface.

(10) A relief well is completed after 15 days; the exploratory well would flow to the Lake during this time.

b. Fate of Residuals and Materials Selected for Modeling Analysis

(1) 20 bbl/day of oil is released to the Lake.

(2) 300 MCF of natural gas is released to the Lake at the sediment/water interface where some of the gas would dissolve; the greatest volume fraction of gas would rise to the surface.

c. Modeling Results

(1) The interaction of oil with the lake environment will be complex and highly dependent upon ambient conditions; the oil will tend to rise to the surface initially and will be blown to shore if the wind is blowing with sufficient speed in the right direction; some of the oil will be lost to the atmosphere through evaporation and some will be incorporated into the water column, by dissolution and emulsification; concentrations of dissolved hydrocarbons from an oil spill were not predicted.

(2) It is difficult to predict what fraction of natural gas (and each of its components) will dissolve in the Lake; values of dissolved gases measured over presumed Lake Erie gas seeps (Zapotosky and White 1980) were used as surrogate values:

Residuals	Concentration at Release Point (mg/L)
Methane	7.500
Ethane	0.360
Propane	0.060
n-Butane	0.014
Isobutane	0.006

C.005

2. Jack-up Rig Capsize with Loss of Rig Inventory to Lake (Lowest Frequency Category)

a. Accident Assumptions

(1) Severe weather, collison while under tow, failure in jacking hardware, or blowout-erosion of supporting sediments causes rig to capsize.

(2) The entire rig inventory (see Appendix B, Table B.2) is dumped into the Lake; depending on the nature of inventory containers, the containers may (a) sink to the lake bottom and remain intact, (b) rupture immediately upon capsize, or (c) slowly leak materials to the Lake after settling to the lake bottom.

b. Fate of Residuals and Materials Selected for Modeling Analysis

(1) All liquid polybrine drilling fluid (300 bbl) is released from open storage tanks; 10% of the drilling fluid dissolves instantaneously in lake water, the remainder sinking to the bottom; only the $CaCl_2$ component of the drilling fluid is modeled.

(2) Diesel fuel drains from ruptured storage tanks at a rate of 667 gal/h for 24 h.

(3) Dry $CaCl_2$ in 100-lb sacks is dumped into the Lake; some sacks rupture, causing 10% of the $CaCl_2$ (6000 lb) to dissolve instantaneously.

(4) Dry chrome lignosulfonate in 100-lb sacks is dumped into the Lake; some sacks rupture causing 10% of the mud additive (50 lb) to dissolve instantaneously.

(5) Dry barite in 100-lb sacks is dumped into the Lake; some sacks rupture, and 10% of mud additive (500 lb) remains in suspension.

c. Modeling Results

(1) Concentrations of materials are as follows:

Material	Concentration (mg/L) At Release Point	At 0.5 mile
Polybrine fluid		
Ca^{++}	4000	0.1
Cl^-	8000	0.2
Dry mud additive		
Ca^{++}	5000	0.1
Cl^-	9000	0.2
Chrome lignosulfonate[a]	100	0.003
$BaSO_4$	1000	0.03

[a]Concentrations as chrome lignosulfonate. The chromium content is variable, but about 3%.

(2) The interaction of diesel fuel with the environment will be complex and highly dependent upon ambient conditions; the diesel fuel will tend to rise to the surface initially and will be blown to shore if the wind is blowing with sufficient speed in the right direction; some of the diesel fuel will be lost to the atmosphere through evaporation and some will be incorporated into the water column by dissolution and emulsification; concentrations of dissolved diesel fuel hydrocarbon components were not predicted.

C.006

3. Stimulation Barge Capsize with Loss of Barge Inventory to Lake (Lowest Frequency Category)

a. Accident Assumptions

(1) Severe weather, collision while under tow or at site, or accident during well stimulation causes barge to capsize.

(2) The entire barge inventory (see Appendix B, Table B.4) is dumped into the Lake; depending on the nature of inventory containers, the containers may (a) sink to the bottom of the Lake and remain intact, (b) rupture immediately upon capsize, or (c) slowly leak materials to the Lake after settling to the lake bottom.

b. Fate of Residuals and Materials Selected for Modeling Analysis

(1) Dry $CaCl_2$ in 100-lb sacks is dumped into the Lake; all sacks rupture, causing 7500 lb of $CaCl_2$ to dissolve instantaneously.

(2) Storage tanks are ruptured, releasing liquid HCl into the Lake; 1500 gal of 15% HCl dissolve instantaneously.

(3) Surfactant container(s) is ruptured, releasing liquid surfactant (specific gravity = 1.0) into the Lake; 75 gal dissolves instantaneously.

c. Modeling Results

(1) Concentrations of materials are as follows:

	Concentration (mg/L)	
Material	At Release Point	At 0.5 mile
Dry stimulation fluid component		
Ca^{++}	600	0.02
Cl^-	1000	0.03
15% HCl	7000	0.2
Surfactant (specific gravity = 1)	1000	0.0004

C.007

4. Developmental Well Blowout (Lowest Frequency Category)

a. Accident Assumptions

(1) After drilling through the Lockport Formation and into Clinton-Medina sandstones, large and uncontrollable circulation fluid loss lowers wellbore column pressure to below Lockport Formation pressure.

(2) Liquids and gas migrate up wellbore; technological failure in all BOP equipment--i.e., hydril, pipe rams, blind rams--results in uncontrolled flow of gases and liquids to the rig.

(3) Liquids conducted up the wellbore are displaced to mud tanks; mud tanks eventually overflow.

(4) Gases are separated from liquids at the rig deck and vented or flared to the atmosphere.

(5) If reservoir pressures are high enough to fracture confining wellbore formations or the cement bond around any casing string, liquids could be forced outside of the wellbore; under worst-case conditions, formation fractures could conduct liquids upward resulting in direct displacement of all fluids to the Lake at the sediment/water interface.

(6) A relief well is completed after 15 days; the developmental well would flow to the Lake during this time.

b. Fate of Residuals and Materials Selected for Modeling Analysis

(1) Formation fractures conduct 950 MCF/day of gas to the sediment/water interface where some of the gas would dissolve; the greatest volume fraction of gas would rise to the surface.

(2) Formation fractures conduct 0.15 bbl/day of petroleum condensates to the sediment/water interface where the condensate would completely dissolve.

(3) Formation fractures conduct 470 lb/day of gaseous H_2S to the sediment/water interface; the H_2S would completely dissolve.

c. Modeling Results

(1) It is difficult to predict what fraction of natural gas (and each of its components) will dissolve in the Lake. Values of dissolved gases measured over presumed Lake Erie gas seeps (Zapotosky and White 1980) were used as surrogate values; concentrations of condensate hexane and hydrogen sulfide were calculated through modeling analysis:

	Concentration (mg/L)	
Residuals	At Release Point	At 0.5 mile
Methane	7.500	
Ethane	0.360	
Propane	0.060	
n-Butane	0.014	
Isobutane	0.006	
Condensate hexane	10	0.005
Hydrogen sulfide	10	0.006

C.008

5. Rupture of 8-inch Gas Flowline and Glycol Feeder Line (Moderate Frequency Category)

a. Accident Assumptions

(1) Large anchors dropped during bad weather or ice scour sever a natural gas flowline and adjacent glycol feeder line.

(2) The safety valve at the juncture of the trunk line and flowline fails to actuate and shut in the field of producing wells.

(3) Gases and liquids from a field of 25 wells are released to the Lake.

(4) The field-pressure drop is detected at the onshore production facility after 24 h; glycol injection is immediately stopped; divers are sent to the line break and repair the leak 3 days after the accident occurs (severe meteorological conditions, e.g., high winds and nearshore ice buildup, impede efforts to reach the line break).

b. Fate of Residuals and Materials Selected for Modeling Analysis

(1) The flowline rupture releases 23.75 MMCF/day of gas to the Lake; some of the gas would dissolve, but the greatest volume fraction of gas would bubble to the surface.

(2) The flowline rupture leaks 0.16 bbl/MMCF of petroleum condensates to the Lake (3.8 bbl/day); the condensate would dissolve completely.

(3) The flowline rupture releases 11,700 lb/day of gaseous H_2S to the Lake; the H_2S would completely dissolve.

(4) 64.8 bbl/day of glycol is released to the Lake for one day; the glycol would completely dissolve.

c. Modeling Results

(1) It is difficult to predict what fraction of natural gas (and each of its components) will dissolve in the Lake. Values of dissolved gases measured over presumed Lake Erie gas seeps (Zapotosky and White 1980) were used as surrogate values;

concentrations of condensate hexane, hydrogen sulfide, and di- and triethylene glycol were calculated through modeling analysis:

Materials and Residuals	Concentration (mg/L)	
	At Release Point	At 0.5 mile
Methane	7.500	
Ethane	0.360	
Propane	0.060	
n-Butane	0.014	
Isobutane	0.006	
Condensate hexane	300	0.01
Hydrogen sulfide	300	0.1
Di-, Triethylene glycol	20	1

REFERENCE

Zapotosky, J.E., and W.S. White. 1980. A Reconnaissance Survey for Lightweight and Carbon Tetrachloride Extractable Hydrocarbons in the Central and Eastern Basins of Lake Erie: September 1978. Argonne National Laboratory Report ANL/ES-87 (Draft). Prepared for U.S. Army Corps of Engineers and U.S. Environmental Protection Agency. 94 pp. (in preparation).

APPENDIX D. SUMMARY OF EXISTING RULES AND REGULATIONS AND PROPOSED GUIDELINES THAT MAY BE USED TO DEFINE AN ACCEPTABLE OFFSHORE NATURAL GAS DEVELOPMENT PROGRAM IN U.S. WATERS OF LAKE ERIE

I. EXISTING FEDERAL AND STATE STATUTES, REGULATIONS, AND PERMIT REQUIREMENTS

A. Federal Statutes

D.001
The following material referes to laws identified in Table 1-10 of this report. Federal statutes identified as relevant to the management and operation of a U.S. Lake Erie natural gas resource development program, regulations issued pursuant to authority granted by these statutes, and permitting requirements established thereunder, as of July 1, 1979, are summarized below.

D.002
1. Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977, 33 U.S.C. 1251 et seq., which has as its objective to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Federal regulations cited whose authority derives all or in part from this Act are:

   - Oil Pollution Prevention, 40 CFR Part 112, which requires preparation and implementation of a plan conforming to specified procedures, methods, equipment, and other requirements to prevent discharge of oil from nontransportation-related onshore and offshore facilities.

   - National Pollution Discharge Elimination System, 40 CFR Part 122, which defines the NPDES, including permitting programs under Sections 318, 402, and 405 of the Clean Water Act. These regulations apply to state NPDES programs, as well, to a limited extent. Permit conditions--including duration, compliance monitoring, modification, and revocation--are treated in this Part. Permit: NPDES (Section 402).

   - USEPA Interim Regulations on Discharge of Dredge or Fill Material into Navigable Waters, 40 CFR Part 230, which provide guidelines for issuance of permits under Section 404(b) of the Clean Water Act. Permit: Dredge or Fill (Section 404).

   - State Permit Program Requirements, 40 CFR Part 123, which deal with NPDES permit program requirements under Sections 318, 402, and 405 of the Clean Water Act, and with dredge and fill permit program requirements under Section 404 of the Clean Water Act, with which compliance is required for state programs to obtain approval of the Administrator of the USEPA.

   - Procedures for Decision Making Regarding NPDES Permits, 40 CFR Part 124, which specify procedures for permits and permit appeals, including hearings, variances, statutory modifications, and public access to information.

   - Criteria and Standards for the NPDES, 40 CFR Part 125, which establish criteria and standards for imposition of technology-based treatment requirements in permits issued under Section 301(b) of the Clean Water Act, including USEPA-promulgated effluent limitations and case-by-case determinations of effluent limitations under Section 402(a)(1).

- Oil and Gas Extraction Point Source Category, 40 CFR Part 435 (Subchapter N), which establishes guidelines for effluent limitations using best practical control technology currently available (BPCTCA), for sources located offshore, onshore, and in coastal regions.

- National Oil and Hazardous Substances Pollution Contingency Plan, 40 CFR Part 1510, issued by the Council on Environmental Quality, which provides for coordinated federal action to try to prevent discharges of oil and hazardous substances, and to protect the environment from damage when discharges occur.

D.003

2. Clean Air Act, as amended, 42 U.S.C. 7401 et seq. (formerly 42 U.S.C. 1857), which has, as its first purpose, to protect and enhance the quality of the nation's air resources so as to promote the public health and welfare and the productive capacity of its population. Federal regulations cited above whose authority derives all or in part from this Act are:

   - Requirements for Preparation, Adoption, and Submittal of Implementation Plans, 40 CFR Part 51, which set standards for state implementation plans for management of air quality. The USEPA's Emission Offset Interpretative Ruling, under 40 CFR 51.18 and Section 129 of the Clean Air Act, states USEPA's policy on review of new sources or modifications that would contribute to violation of NAAQS, to assure progress towards attaining air quality standards by requiring compensating reductions in emissions from existing sources before new sources of pollutants can be permitted within a nonattainment area.

   - Prevention of Significant Deterioration of air quality, 40 CFR 52.21, which delineates provisions that are automatically included in any state implementation plan whose PSD provisions have been disapproved by the Administrator of the USEPA. Permit: Preconstruction Review (PSD).

D.004

3. Coastal Zone Management Act of 1972, as amended, 16 U.S.C. 1451 et seq., which declares that it is the national policy to preserve, protect, develop, and, where possible, restore or enhance the resources of the nation's coastal zone for this and succeeding generations; to encourage and assist the states to excercise effectively their responsibilities in the coastal zone through the development and implementation of management programs to achieve wise use of the land and water resources of the coastal zone giving full consideration to ecological, cultural, historic, and esthetic values as well as to needs for economic development. Federal regulations cited above, whose authority derives all or in part from this Act are:

   - Coastal Zone Management Program Approval Regulations, 15 CFR Part 923, which sets criteria and procedures for reviewing and approving of state coastal zone management programs.

D.005

4. Safe Drinking Water Act, 42 U.S.C. 300f et seq., which provides for the safety of public water systems.

D.006

5. River and Harbor Act of 1899, 33 U.S.C. 401 et seq., which relates to the protection of navigable waters and of harbor and river improvements generally. Section 10 of the Act, 33 U.S.C. 403, requires approval by the Chief of Engineers and the Secretary of the Army before obstruction of navigable waters, construction of wharves or piers, or excavations and filling in may be carried out.

D.007

6. Resource Conservation and Recovery Act of 1976, as amended, 42 U.S.C. 6901 et seq., which has as its objective to promote the protection of public health and the environment and to conserve valuable material and energy resources. Solid wastes requiring onland disposal are subject to RCRA regulations.

B. State Statutes

D.008

State statutes relevant to the management and operation of a U.S. Lake Erie natural gas resource development program, regulations issued pursuant to authority granted by these statutes, and permitting requirements established thereunder, as of July 1, 1979, are summarized below:

D.009

1. Ohio Water Pollution Control Act, Ohio Revised Code, Section 6111.01 et seq., which prohibits acts of pollution. Regulations whose authority derives from this Act are:

   - Ohio Water Quality Standards, Ohio Administrative Code 3745-1 to 3745-1-14.

   - Ohio NPDES Permit Regulations, Ohio Administrative Code 3745-33-01 through 3745-33-10. Permits: Ohio NPDES; Liquid Disposal (underground injection); Industrial Water Pollution Control Certificate.

D.010

2. Ohio Watercraft Sewage Disposal Law, Ohio Revised Code 1547.33 et seq., which provides that sewage may be discharged from a watercraft into Lake Erie and other specified waters, but only if the watercraft is equipped with an approved sewage disposal system.

D.011

3. New York Environmental Conservation Law, Article 17, Water Pollution Control, which has as its purpose to safeguard the waters of the state from pollution by preventing any new pollution and by abating existing pollution. Regulations whose authority derives from this Act are:

   - New York Regulations on SPDES, NYCRR Title 6, Chapter 10, §§ 750-757. Permit: SPDES.

- New York Pollution Control Regulations, NYCRR Title 6, Chapter 5, Subchapter D, §§ 608-611. Permits: Dams and Docks; Excavation or Placement of Fill; Discharge into Navigable Waters.

D.012
4. New York Navigation Law. Certification required from the Department of Transportation for operation of major onshore petroleum facilities.

D.013
5. Pennsylvania Clean Streams Law, Act 394, Pub. L. 1987, June 22, 1937, as amended. Regulations issued pursuant to the Act are:

   - Pennsylvania Water Resources Regulations, Pa. Code, Title 25, Part 1, Article 2, §§ 91-101. Permits: Sewage Discharge; Activity Creating Danger of Pollution; NPDES.

II. PROPOSED GUIDELINES

A. Administrative Procedures

D.014
1. A Task Force of appropriate federal and state representatives will be created to guide program development. The Task Force will develop standard lease forms, drilling permit forms, and construction and operation permit forms. The Task Force will be responsible for ultimately defining a minimum set of federal standards to guide offshore development activities. The Task Force would also draft the necessary enabling legislation to authorize gas drilling and would create a standing review committee representing appropriate federal and state parties. (p. 1-37)

D.015
2. Each state will develop and implement a program designed specifically for production of natural gas from under its waters. Each state will use a common baseline set of operating standards as specified by the Task Force in its program. (p. 1-36)

D.016
3. All offshore program-related activities will be coordinated by one designated state agency in each participating state (offshore program office). (pp. 1-36, 1-38)

D.017
4. The state offshore program office will be the lead agency in coordinating the state and federal agencies' regulatory actions over offshore gas development. (p. 1-36)

D.018
5. Each state will develop its own requirements for competitive bidding, rental fees, royalty fees, insurance bonds, and other financial matters. (p. 1-38)

D.019
6. Financial support for administrative functions will originate from operator payments to the states as stipulated in the lease provisions for competitive bidding, annual rental, and royalties. (p. 1-41)

B. Disclosure and Review Requirements

D.020

1. All operators must submit the following information to the offshore program office for approval prior to initiating offshore gas development activities:

   - drilling program (depths to target formation, drilling fluids, drillpipe, bits, blowout prevention equipment, aboard liquid/gas separators, solids control system, etc.)

   - casing program including cementing procedures

   - well completion programs (perforation procedures, completion fluids, production tubing, well cleaning, etc.)

   - plugging and abandonment procedures

   - well and pipeline decommissioning procedures

   - proposed pipeline routes and construction and operation procedures

   - waste handling and treatment/disposal strategy

   - other information as requested by the offshore program office

   The above activities must represent state-of-the-art offshore oil and gas development and production technologies. The above information will be reviewed by the offshore program office and compared to acceptable industry performance standards (including those outlined in this Draft EIS). The offshore program office will evaluate each proposal on the basis of anticipated site-specific hazards and available technological/operational solutions. (pp. 1-29, 1-57)

D.021

2. Operators must periodically provide the offshore program office with an inventory (quantity and chemical composition) of all chemicals stored and/or used on program rigs and vessels, e.g., completion fluid and drilling fluid components, stimulation materials, and all other chemicals used to develop and produce offshore gas. (p. 1-78, Appendix B)

D.022

3. When requested by the offshore program office, operators will be required to monitor the quantities of all liquid hydrocarbons encountered upon formation tests and report results. (pp. 1-21, 1-37)

D.023

4. Operators will be required to monitor the quantities and chemical composition of produced formation water and liquid hydrocarbons that accompany natural gas to shore after a well is completed. The results will be reported to the offshore program office. (pp. 1-78, 1-84)

   Although most gas wells drilled in the Reference Program Study Region could indicate production of only dry gas upon initial well tests, overall gas reservoir analysis suggests that small amounts of liquid

hydrocarbons could be entrained in the gas stream along with formation water. Additionally, a small fraction of Reference Program dry gas wells could start to produce increasing amounts of liquid hydrocarbons as the wells age and reservoir pressures decline. A determination of whether any and, if so, how much liquid hydrocarbons will be allowed to be produced from completed "dry wells" must be made, based on program experience. (p. 1-23)

D.024

5. When requested by the offshore program office, an operator will be required to provide site-specific data--e.g., bottom topography, physical and chemical properties of sediments, bioassays, sediment depth, and, if possible, a determination of the source of the sediment--characterizing a proposed wellsite prior to approval of a drilling program. Sampling and analyses will be performed at the operator's expense. (p. 4-21)

D.025

6. All waste materials caused to be generated by an operator must be continuously monitored. As mandated by the offshore program office, minimum requirements will be (a) measurement of quantities collected, stored, and transported to shore and (b) periodic identification of physical and chemical properties of waste stream components. Quantities and properties must be reported to the offshore program office. This information will be used to design an appropriate waste treatment/ disposal strategy. Monitoring and analysis procedures must be approved by the offshore program office and undertaken at the operator's expense. (p. 1-84)

D.026

7. When requested by the offshore program office, an operator will be required to provide site-specific environmental data characterizing a proposed pipeline landfall and detailed engineering design information. This information will be collected and provided at the operator's expense. (p. 4-1)

C. Environmental/Operational Constraints

D.027

1. Drilling will be prohibited in the following areas: (pp. 1-7, 1-30, 1-34, 1-52)

   - in the western basin (west of a line drawn between Marblehead, Ohio, and Pt. Pelee, Ontario, including Sandusky Bay, Ohio) until the United States and Canada are satisfied that containment and cleanup methods and the contingency plans for oil spills are adequate

   - designated dredge disposal areas (Figure 1-1, map pocket)

   - a designated buffer zone around Presque Isle, Pennsylvania (Figure 1-1, map pocket)

   - a designated buffer zone within one mile from shore (Figure 1-1, map pocket)

- within a 0.5-mile strip of lakebed adjacent (on each side) to state and national jurisdictional boundaries.

D.028
2. Drilling will be prohibited and underwater pipelines are excluded within 0.5 mile from a potable water intake and within 1000 ft from any other physical structure. (p. 1-30)

D.029
3. Leasing of existing and potential sand and gravel areas must be postponed until such time as the offshore program office is confident that interest in extraction is insigificant. (p. 1-30)

D.030
4. An open drilling season will be designated that prohibits offshore activities when there is a significant chance of hazardous seasonal weather: (pp. 1-25, 1-28)

	Open Season
New York	May 1 - October 31 (184 days)
Pennsylvania	April 1 - October 31 (214 days)
Ohio	April 1 - October 31 (214 days)

D.031
5. Gas storage in reservoirs beneath Lake Erie will be prohibited until offshore production history can be adequately evaluated by the Task Force. (p. 1-74)

D.032
6. The following areas must be avoided in pipeline routing: steep slopes, anchorage areas, existing underwater objects, active faults, rock outcrops, and environmentally sensitive areas (p. 1-96)

D.033
7. The following areas must be avoided when siting pipeline landfalls: high erodible bluffs, densely populated urban areas, productive streambeds, wetlands, recreational areas, and other areas designated by the offshore program office. (p. 1-96)

D.034
8. Gas production facilities must be sited away from densely populated areas to avoid subjecting humans to excessive noise or smell or to explosion risk. (p. 1-97)

D.035
9. Any well that indicates a production potential of 5 gal/day or more of natural gas liquids at the initial formation test must be plugged and abandoned. If the formation test indicates a production potential of less that 5 gal/day, the liquid zone could be cased off and production from other dry zones pursued. (pp. 1-21, 1-39)

D.036
10. Cable-tool drilling equipment will be prohibited from use. (p. 1-57)

D.037
11. Oil-based drilling fluids will be prohibited from use. (p. 1-57)

D. Performance Standards

D.038
1. Development and Production Technology

- All wells must be adequately marked. (p. 1-59)

- State-of-the-art blowout prevention equipment must be used during the course of drilling each well. (pp. 1-59, B-5, B-8)

- State-of-the-art solids control equipment must be used during the course of drilling each well. (pp. 1-57, B-5, B-8)

- Wherever possible, surface casing (drive pipe) must be set between the water/sediment interface and consolidated bedrock. Also, a riser pipe must be connected between the drive pipe and rig deck to ensure closed-cycle drilling wherever possible. (p. 1-57)

- Wherever possible, wellbore casing must be used to the total depth of each well. (p. 1-57)

- When developing offshore gas wells or onshore injection wells, water-bearing strata must be sealed and isolated from the wellbore using appropriate casing material. (p. 1-39)

- Use of jack-up rigs will be limited to lake areas where an adequate air gap can be maintained between the lake surface and rig platform, i.e., areas where sediment depth and water depth do not exceed leg length, plus an adequate air gap and a margin of safety. (pp. 1-28, 1-31)

- Use of jack-up rigs will be restricted from lake areas where rig legs will sink to sediment depths greater than 15 ft unless an operator can demonstrate, to the satisfaction of the offshore program office, that a specific rig under site-specific conditions can jack-down and move offsite without jeopardizing life, property, or the environment. (pp. 1-28, 1-31)

- If problems in jack-up rig stability are encountered while pulling out of sediments, all bulk materials, drilling fluids, and excess diesel fluid must be offloaded from the rig to a service barge. (p. 1-62)

- Drip pans, interior and exterior pipe wipers, mud pit monitors, and kick detectors must be used on all drilling rigs. This equipment must be approved by the offshore program office. (p. 1-57)

- On wells drilled by jack-up rigs in consolidated sediments, wellheads must be placed below the water/sediment interface in cellars (caissons) wherever possible. (pp. 1-28, 1-57)

- Each well must be completed to prevent high field pressures from damaging the reservoir of a lower-pressure well. (p. 1-98)

- All free liquids must be separated from produced gas at approved onland gas process/treatment facilities. (p. 1-73)

D.039

2. Material Handling and Waste Treatment/Disposal

   - The following materials used or residuals generated must be collected aboard rigs or vessels and brought to shore for approved treatment and/or disposal: (pp. 1-39, 1-74, 1-86)

     - precompletion formation water
     - drilling fluids
     - deck drainage
     - completion fluid
     - spent acid
     - stimulation returns
     - drill cuttings
     - excess cement
     - sanitary waste
     - domestic waste

   - All materials used and residuals generated that are designated for shore disposal must be stored in approved, closed containers while awaiting transport to shore. (p. 1-57)

   - Produced waters must be reinjected into suitable onshore host formations or disposed of onshore in approved surface pits. (p. 1-39)

   - Materials that flow back from a well after stimulation must be collected until flow from the well is insignificant (< 10 gpm). After an insignificant return flow rate is achieved, a stimulated well will be allowed to flow open to the environment (on camel) for a period up to 12 hours. (p. 1-72)

   - Any gas containing a significant amount of H_2S ($\geq$ 0.25 grains H_2S/0.1 MCF of gas) cannot be commingled with gas containing insignificant amounts of H_2S (< 0.25 grains H_2S/0.1 MCF). (p. 1-50)

   - All rigs and vessels must have aboard (a) H_2S detection devices, (b) personnel safety equipment (oxygen packs), and (c) visual warning devices to warn boaters of encounters with H_2S or other hazardous or toxic gases. (p. 1-29)

   - All rig personnel must be trained for participation in contingency plans for rig or vessel accidents. (p. 1-29)

   - H_2S must be reduced to < 0.25 grains/0.1 MCF of gas at onshore treatment plants. All pipelines, wellheads, and other hardware transmitting gas that could contain H_2S must be constructed of materials that will resist corrosion from H_2S. (p. 1-22)

D.040

3. Pipelines

   - Underwater pipeline networks must be designed to transmit gas from all producing wells through the smallest possible number of flowlines to shore. (p. 1-72)

- Underwater pipeline networks must be routed to the smallest possible number of landfalls while maintaining efficient long-term gas production. (p. 1-72)

- All underwater gas flowlines and glycol feeder lines must follow the shortest distance between a trunk line and a designated landfall. (p. 1-96)

- A pressure-drop-actuated safety valve must be connected at a strategic location at the junction of a trunk line and flowline to shut in the entire field in the event of a line break. (p. 1-98)

- Pipelines within the 30-ft water depth contour must be buried to a depth of between 5 and 10 ft (actual depth will be based on site-specific conditions) to avoid damage from nearshore ice pileups. (pp. 1-28, 1-41, 1-93)

- All pipeline landfalls must be constructed to ensure protection of the pipelines and land that they traverse. (p. 1-96)

- All pipelines routed between a landfall and an associated onland gas process/treatment facility must be constructed on a single corridor using state-of-the-art impact mitigation procedures. (p. 1-72)

D.041

4. Facility Siting and Construction

- Before any topographic adjustments are made as a result of siting a rig or constructing any facility or structure, an approved survey of the area for archeological and/or cultural resources must be performed using state-of-the-art techniques. (p. 1-59)

- A land/soil suitability-constraint analysis must be performed to select optimal sites for pipeline landfalls and onland facilities. (pp. 1-30, 1-94)

- Landfalls and onland pipeline corridors must be stabilized against erosion using state-of-the-art technology. (p. 1-30)

- Pipelines, landfalls, and other facilities must be constructed to withstand ice and wind damage from a 100-year storm. (p. 1-39)

- Gas process/treatment facilities and waste treatment/disposal facilities must be set back an appropriate distance inland from the shoreline to minimize coastal zone land-use conflicts and esthetic impacts. (p. 1-72)

- In order to minimize siting problems and land requirements in the coastal zone, operators will be encouraged to enter into joint agreements where appropriate to construct and operate gas process/treatment facility(s) and waste treatment/disposal facility(s). (pp. 1-72, 1-93, 4-32)

APPENDIX E. LITERATURE SURVEY OF LAKE ERIE LIMNOLOGY AND CRITICAL CONTAMINANT LOADINGS AND CONCENTRATIONS*

*The material in this appendix has been excerpted verbatim (excluding style changes) from: McGregor, D.L., et al. 1978. An Examination of Issues Related to U.S. Lake Erie Natural Gas Development. Argonne National Laboratory Report ANL/ES-68. Prepared for the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency by the Division of Environmental Impact Studies, Argonne, IL. 194 pp.

INTRODUCTION

E.001
Lake Erie, the southernmost of the Great Lakes, is located between 42°45' and 42°50' north latitude and 78°55' and 83°30' west longitude. The Lake is oblong in shape with its longest axis oriented at about 70° east of north. It has a total length of 386 km (240 mi), a mean width of 71 km (44 mi), and can be divided into three sub-basins (Figure E.1). The western basin is separated from the central basin by a rocky underwater rise and a chain of islands between Pt. Pelee, Ontario, and Marblehead, Ohio. A wide sandy ridge, extending from Long Point, Ontario, to Presque Isle, Pennsylvania, separates the central from the eastern basin. Much of the Lake is shallow with mean depths of 11 m (36 ft), 25 m (82 ft), and 64 m (210 ft) for the western, central, and eastern basins, respectively (Burns and Ross 1972; Sly 1976).

E.002
Historical evidence of cultural development within the Lake Erie watershed (Figure E.2) suggests that impact upon water quality was localized until the 1900s when intensive industrialization began (Sly 1976). The heavy and diversified industrial growth of the southern shore (United States) was paralleled by a slower and less broadly based agricultural development in the northern portion of the drainage basin (Canada). This led to a gradual increase in anthropogenic, atmospheric, and tributary loading, primarily from the southern shore. Today Lake Erie is utilized as a resource for a multiplicity of industrial, municipal, commercial, and recreational purposes. Since all these activities have an effect on the physical, chemical, and biological conditions of the Lake, Lake Erie water quality at any one place or time is the product of a series of complex chemical, biological, and physical interactions involving processes within and outside of the Lake. These processes may be of geologic, biogenic, anthropogenic, or atmospheric origin. Therefore, chemicals released from natural and cultural activities enter one or a combination of three media: air, water, or soil. Rarely, if ever, do materials reside very long in any one medium.

E.003
The phase association of a nutrient or contaminant with water, sediments, and biota in Lake Erie reflects its biogeochemical cycle. Spatial and temporal distribution relates to oxidation-reduction conditions, diffusion and disturbance exchanges from sinks, and physical mixing within the lake basin. Past loading of nutrients and contaminants from all sources is reflected, in part, in present biological and chemical conditions.

CONTAMINANT LOADING

E.004
The accumulation of heavy metals, other contaminants, and nutrients in Lake Erie has contributed to the degradation of water quality and to the alteration of biological communities in the Lake (Beeton 1965). Although the sources of many of these metals are natural, wastes of anthropogenic origin have greatly augmented the rate of loading. Upchurch (1972) estimated that 53% of the heavy metal loading to Lake Erie was anthropogenic in origin. The two major sources of this loading are effluent discharges of municipal wastes (Table E.1) and industrial wastes entering Lake Erie from its tributaries (Table E.2). Anthropogenic input to Lake Erie of mercury, lead, zinc, and cadmium exceeds that derived from natural weathering and atmospheric deposition (Table E.3).

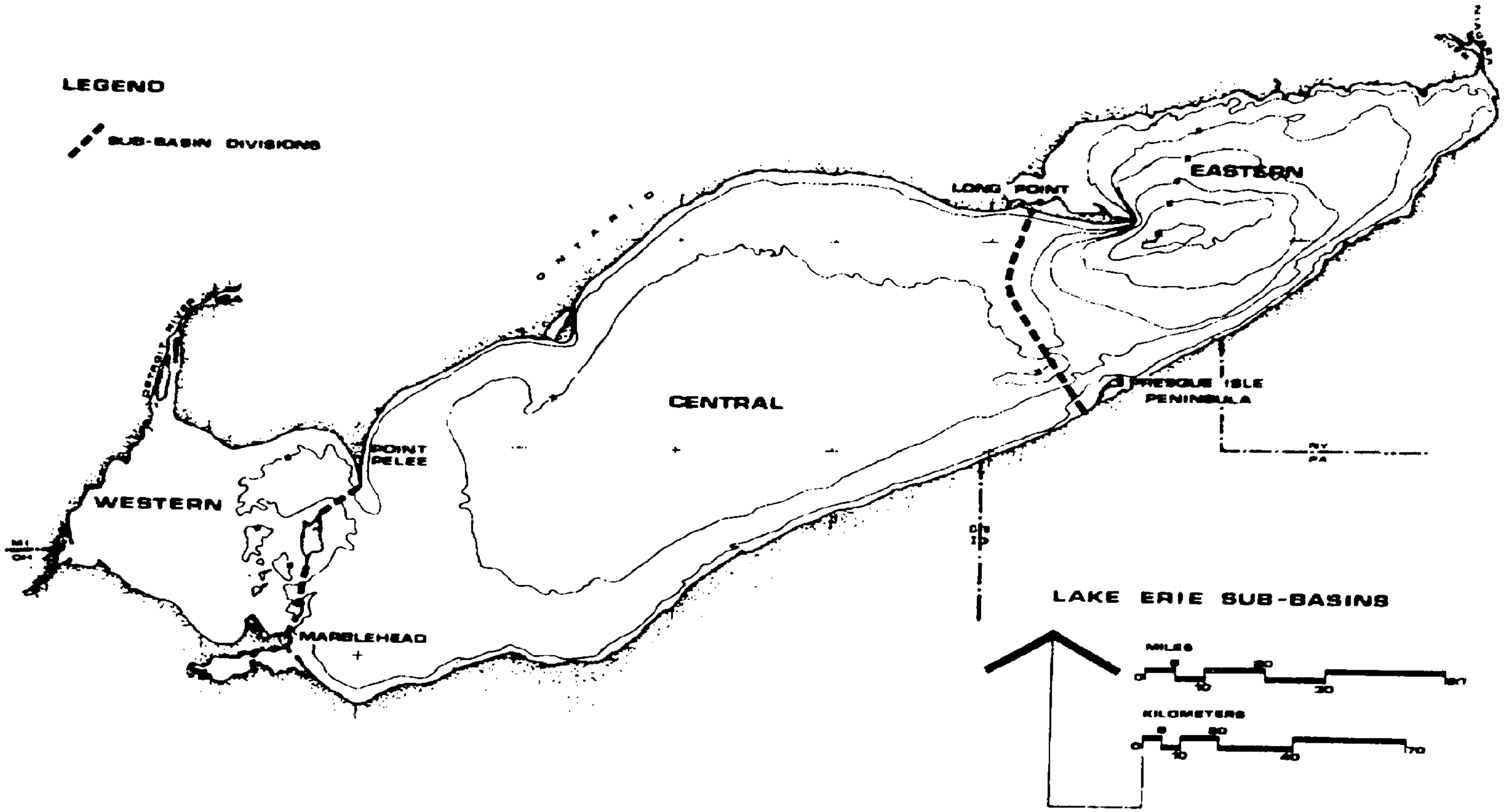

Figure E.1. The Structural Sub-basins of Lake Erie. Contour intervals are 10 m (33 ft).

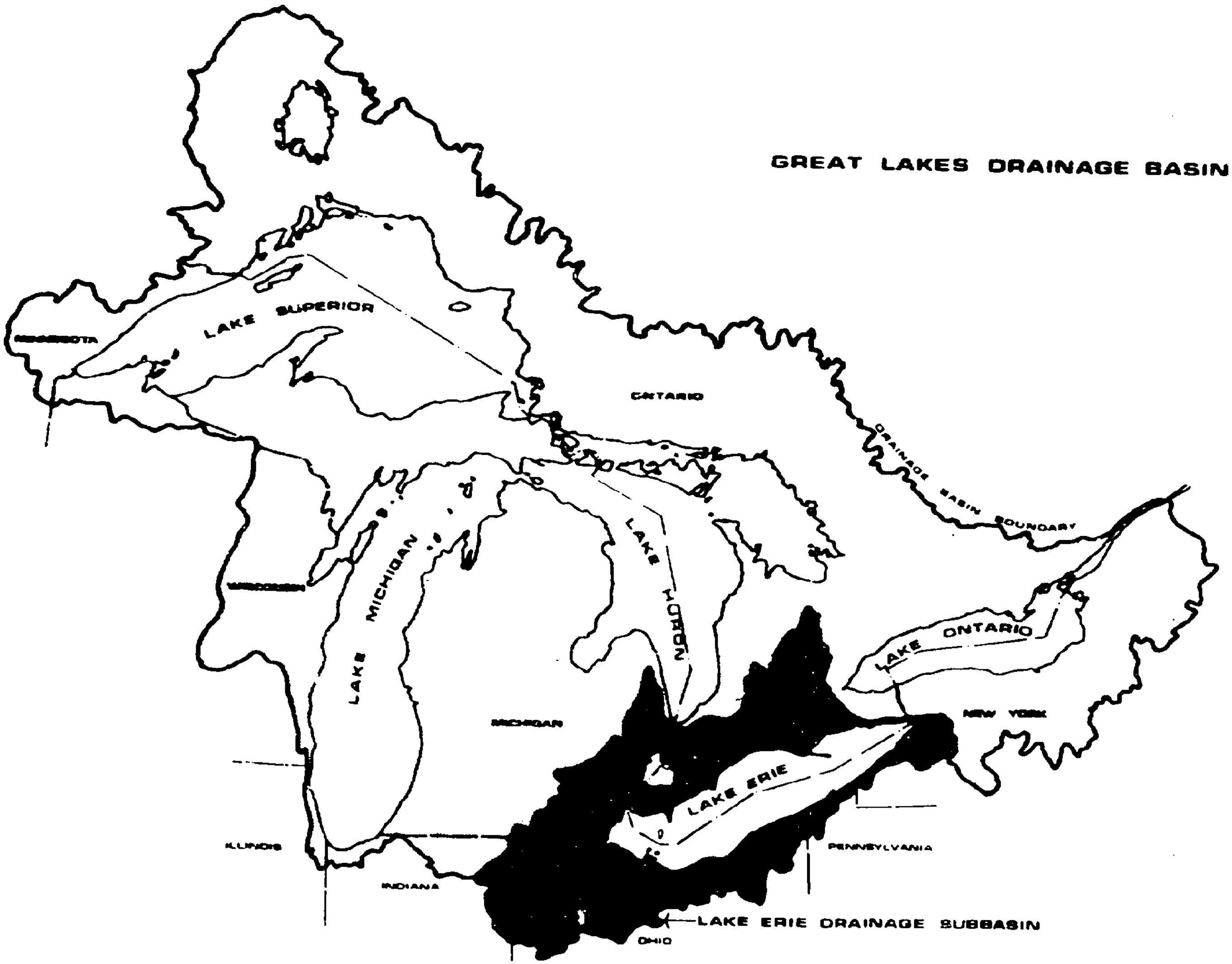

Figure E.2. Location of Lake Erie and Its Associated Watershed in the Great Lakes Drainage Basin.

Table E.1. Municipal Loading of Heavy Metals to Lake Erie, 1975 to 1976[a]

Metal	Concentration (µg/L)[b]	Flow Rate (L/day)	
		Average	Range
As	<2.0 - <5.0	7.0×10^7	$1.5 \times 10^4 - 3.6 \times 10^5$
Cd	<8.0 - 18.0 (124)	6.4×10^7	$3.8 \times 10^3 - 4.5 \times 10^5$
Cr	<5.0 - 69.0 (460)	6.4×10^7	$3.8 \times 10^3 - 4.5 \times 10^5$
Cu	<5.0 - 54.0 (166)	6.4×10^7	$3.8 \times 10^3 - 4.5 \times 10^5$
Hg	<0.1 - 0.5 (0.6)	6.4×10^7	$3.8 \times 10^3 - 4.5 \times 10^5$
Ni	<2.0 - 300.0	3.9×10^7	$1.0 \times 10^4 - 4.5 \times 10^5$
Pb	<10.0 - 920.0	6.4×10^7	$3.8 \times 10^3 - 4.5 \times 10^5$
Zn	30.0 - 1400.0 (3850)	6.4×10^7	$3.8 \times 10^3 - 4.5 \times 10^5$

[a]Data from Konasewich et al. (1978).

[b]Numbers in parentheses represent the highest influent concentration measured.

Table E.2. Concentrations of Heavy Metals in Waters of Lake Erie Tributaries[a]

River	Date	No. of Samples	Concentration (µg/L)[b]										
			As	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
Huron	1973-1977	5	2-3[d]	0.3-2	-	-	4-8[d]	-	<0.2-0.4	-	24	2-33	26-36
Raisin	1973-1977	7	2-3	0.2-2	-	-	14-16	-	<0.2	-	22-24	<1-31	20-30[d]
Maumee	1975-1977	11	-	11	10	3	3	-	-	-	82	20	21
Detroit[e]	1974	12	-	0.5	-	10.5	8.6	1240	2.7	19	20	5.7	74

[a]Sources of data: Huron, Raisin, and Maumee rivers - Konasewich et al. (1978); Detroit River - Environmental Control Technology, Inc. (1974).

[b]"Total" unless otherwise specified.

[c]Samples collected near mouth of the river, except the Maumee where samples were collected in the river basin and represent streamwater background.

[d]Dissolved fraction.

[e]Values represent average concentration of four stations.

E.005
The western basin receives heavy metal input principally from the Detroit and Maumee rivers. Because the Detroit River is an interconnecting channel between Lakes Erie and St. Clair, the origin of some of these heavy metals is the upper Great Lakes. The city of Detroit and adjacent areas contribute heavily with industrial and municipal discharges. Walters et al. (1974) found that mercury loading to the western basin was derived primarily from two chloralkali plants, one located near Sarnia, Ontario, and the other near Wyandote, Michigan.

E.006
The distribution of heavy metals introduced into the Lake correlates with lake currents, tributary loading, and sediment deposition (Int. Joint Comm. 1978). Bottom sediments in the Lake show a varying degree of heavy metal enrichment over concentrations in the water column (Tables E.4-E.6). Recent studies have

Table E.3. Natural, Anthropogenic, and Atmospheric Loading to Lake Erie,[a,b]

Types/Site	Elements (metric tons/year) Cd	Cl	Cu	Hg	N	P	Pb	Zn
Natural								
Eastern basin	14	-	495	0.6	46,140	9,290	370	1,600
Central basin	9	-	200	0.5	11,410	7,585	160	680
Western basin	9	-	170	0.7	7,540	4,635	215	610
Whole Lake	32	-	865	1.8	41,940	24,550	745	2,890
Anthropogenic								
Eastern basin	37	-	385	4.5	46,140	9,290	1,350	3,440
Central basin	19	-	235	5.8	30,540	4,120	725	1,660
Western basin	14	-	165	6.2	9,020	1,185	480	915
Whole Lake	70	-	785	16.5	85,700	14,595	2,555	6,015
Atmospheric								
Total Lake	150	87,000	330	-	19,000	800	2,200	909

[a]Estimates of natural and anthropogenic loading to Lake Erie were made from (1) pre-settlement (natural background) and post-settlement (post-1850) concentrations of heavy metals from sediment cores collected in the lake, (2) analyses of geochemical and mineral species at 12 shoreline bluff locations, and (3) potential sources and dispersion pathways of lake sediments. Atmospheric loading was calculated from model and precipitation chemistry estimates.

[b]Sources of data: Natural and anthropogenic - Kemp et al. (1976); Atmospheric - International Joint Commission (1977); Cl - Upchurch (1972); Zn - Andren et al. (1977).

Table E.4. Average Concentrations of Heavy Metals in the Water Column of Lake Erie[a]

Location	Concentration (μg/L) Cu	Fe	Mn	Ni	Pb	Zn
Whole Lake (9 stations)	15	156	26	3	4	8
Eastern basin (3 stations)	14	76	13	2	4	10
Central basin (3 stations)	14	145	34	2	4	8
Western basin (3 stations)	17	246	31	4	4	7

[a]Data from Chawla and Chau (1969).

Table E.5. Concentrations of Heavy Metals in Sediments at the Mouth of Twenty Tributaries to Lake Erie[a,b]

Metals	Concentration (μg/g) Average	Range
Ag	0.5	0.1 - 1.4
Cd	0.2	0.6 - 7.8
Co	10.0	6.6 - 14.7
Cr	29.5	3.6 - 124.5
Cu	22.0	1.5 - 69.8
Hg	283[c]	60 - 860[c]
Mn	193.1	53 - 350
Ni	20.6	4.5 - 37.2
Pb	25.4	3.3 - 90.6
Zn	79.6	15.7 - 220.8

[a] Data from Konasewich et al. (1978).

[b] Grand River (Ohio), Lynn River, Big Otter Creek, Catfish Creek, Kettle Creek, Muddy Creek, Raisin River, Maumee River, Portage River, Sandusky Bay Mouth, Huron River, Vermillion River, Black River, Rocky River, Cuyahoga River, Chagrin River, Grand River (Ontario), Ashtabula River, Conneaut River, Silver Creek.

[c] μg/kg.

Table E.6. Heavy Metal Concentrations in Lake Erie Sediment Cores[a]

Location	Sediment Core Interval (cm)	As	Cd	Co	Cr	Cu	Fe	Hg	Ni	Sb	Zn
					Concentration (μg/g)						
Eastern basin (42°40', 79°20')	0-8	0.3	0	6.2	10.0	10.3	10,400	<0.1	10.0	1.1	36.3
	0-80	0.3	0	6.2	10.0	9.5	10,025	<0.1	37.5	0.9	33.5
Central basin (41°30', 82°15')	0-8	2.0	2.6	13.0	47.5	37.0	29,500	0.3	44.5	1.4	23.0
	0-50	1.4	2.1	12.3	36.5	26.0	11,500	0.2	31.8	0.9	17.8
					Enrichment Factor[b]						
Eastern basin[c]	0-80	2.6	-	1.01	1.04	1.2	0.96	3.1	0.48	3.2	1.7
Central basin[c]	0-50	5.0	2.5	1.2	4.5	4.1	1.8	6.6	5.6	3.6	3.3

[a] Data from Walters et al. (1974).

[b] Ratio of concentration in sediment to concentration in water.

[c] Average enrichment factors: eastern basin = 1.7; central basin = 3.8.

shown that mercury concentrations (μg/kg) in the sediments of the western, central, and eastern basins were 1622 ± 694, 544 ± 191, and 483 ± 272 μg/kg, respectively (Thomas and Jaquet 1976). Of the three basins, the eastern receives the highest input of heavy metals. Additions to this basin are primarily from the city of Buffalo and from sedimentation of metals associated with fine-grained sediments carried into the basin by prevailing currents.

E.007
Loading of chlorides, sulfates, and hydrocarbons also is important to the water quality and biological integrity of the Lake (Konasewich et al. 1978). The concentration of chlorides in Lake Erie increased threefold between 1910 and 1964, from 7 μg/mL to approximately 23 μg/mL. The sources of this input were identified to be the Detroit River (27%), municipal effluents (4%), street and highway salting (11%), and industrial wastes (57%) (Ownbey and Kee 1967). Further, the annual loading of chloride to the western basin from the Detroit and Maumee rivers was calculated to be 30 x 10^8 kg/yr (66 x 10^8 lb/yr) and 1.2 x 10^8 kg/yr (2.6 x 10^8 lb/yr), respectively. Later studies indicated that between 1967 and 1977 chloride additions to the entire Lake showed a gradual decrease from approximately 3.7 x 10^9 kg/yr (8.2 x 10^9 lb/yr) to 2.6 x 10^9 kg/yr (5.7 x 10^9 lb/yr) (Konasewich et al. 1978).

E.008
Increased use of fossil fuels for industrial energy requirements has resulted in the elevation of sulfate loading, primarily through atmospheric deposition, to aquatic and terrestrial ecosystems. Acid precipitation has altered lake ecosystems through the introduction of sulfur compounds, heavy metals, and other trace elements, usually resulting in a deleterious effect to the system (Gorham 1976).

E.009
Sulfate (SO_4) loading to Lake Erie has increased since the 1800s. For the early 1960s, Upchurch (1972) reported an annual loading of 13 x 10^8 kg/yr (28.7 x 10^8 lb/yr), only 1.7 x 10^4 kg/yr (3.7 x 10^4 lb/yr) of which he attributed to weathering processes. In 1974, contributions of sulfate to the Lake from U.S. sources amounted to 4.6 x 10^8 kg/yr (10.1 x 10^8 lb/yr) and from Canadian sources to 2.0 x 10^8 kg/yr (4.4 x 10^8 lb/yr), for a total of 6.6 x 10^8 kg/yr (14.6 x 10^8 lb/yr) (Int. Joint Comm. 1977); the inputs represent 69% and 31% of the total, respectively. Of the total atmospheric deposition of sulfate in Lake Erie, 84% originates in the United States and 16% in Canada (Int. Joint Comm. 1977). This difference is probably due to prevailing southwesterly winds and to the location of industrial activity along the southern shore of the Lake. More recent studies indicate that, at present, the total loading of SO_4 to the Lake is on the order of 1.2 x 10^8 kg/yr (2.6 x 10^8 lb/yr) (Konasewich et al. 1978).

E.010
Organic hydrocarbons also may contribute to the degradation of water quality and lake ecosystems. Many persistent forms of chlorinated and other hydrocarbons, such as polychlorinated biphenyls (PCB), either remain in the water column or are concentrated in sediments, transferred through food chains, and bioaccumulated in higher trophic levels. The majority of data for hydrocarbon loadings address pesticides and other synthetic compounds.

E.011
Partitioning of synthetic organic compounds between adsorbed and dissolved phases is unique to each compound Often synthetic organic hydrocarbons are adsorbed onto sediment particulate matter. The rate of adsorption is dependent on the ratio of adsorbent (sediment particle) surface area to mass. Synthetic organic hydrocarbons accumulate in sediments of the Lake (Table E.7). Their concentrations correspond to sedimentation rates in the Lake (highest in the western basin and lowest in the central basin) and suggest an association with the particulate matter in the water column. Considerable information regarding the transport and transformation of pesticides can be found in a recent U.S. Environmental Protection Agency (1978) publication. Little work has been done on either naturally occurring compounds or releases of petroleum products from industrial and municipal sources into Lake Erie.

Table E.7. Average Concentration of Organic Contaminants in Lake Erie Sediments[a]

	Concentration (µg/kg)			
Location	PCB	DDE	TDE	Dieldrin
Eastern basin	86	8.9	17.9	2.3
Central basin	74	7.4	18.3	1.7
Western basin	252	22.1	46.5	1.4
Total	95	8.2	18.4	1.6

[a]Data from Konasewich et al. (1978). PCB = Polychlorinated biphenyls; DDE = Dichloro-diphenyl-dichloroethylene; TDE = Dichloro-diphenyl-dichloroethane.

WHOLE LAKE CIRCULATION PATTERNS

E.012
Water movement is one factor that largely determines the spatial distribution of inert sediments and of particulate and dissolved substances in the three sub-basins. Currents in the Lake are generally variable in direction and velocity; flows outside the immediate influence of the Detroit and Niagara rivers are usually correlative with the direction and intensity of the instantaneous winds and with the fluctuations of seiches. In the western basin, the Detroit River plume extends southeastward and dominates the central area of the basin. The outflow from the basin is primarily at the northern end, between Pelee Island and Pt. Pelee, Ontario (Pelee Passage). Water movements in the interisland region are random, exhibiting little pattern or permanence in direction or speed.

E.013
The principal surface flow in the central basin is first southeast from Pelee Passage then eastward and to the right of the longitudinal axis of the Lake. This pattern exhibits a certain degree of steadiness derived from the direction of the prevailing southwesterly surface wind. During thermal stratification, surface flowage in the central basin may be four times as rapid as that at intermediate depths, and a large horizontal transport can be realized in the thin surface layer. At intermediate depths, the flow regime in the open Lake is diffuse, though predominantly in a westerly direction near the longitudinal axis and easterly along the U.S. shoreline. Surface drift in the central basin has been estimated at 7-10 cm/s (2.8-3.9 in./s) [maximum speeds in excess of 54 cm/s (21.3 in./s) have been recorded] and bottom flow at approximately 0.6 cm/s (0.2 in./s) (Hamblin 1971; Simons 1976). Bottom currents in the central basin show either open-lake or shoreline patterns (Hamblin 1971). Movement immediately along the shore is predominantly eastward, whereas flow near the bottom of the open segment of the central basin is predominantly toward the north. Therefore, material originating on the U.S. side of the Lake and suspended near the bottom is transported toward the Canadian side. This general pattern of water movement is substantiated by drift-bottle studies and the occurrence of upwelling phenomena along the Canadian shoreline (Int. Joint Comm. 1970).

E.014
When the Lake is thermally stratified, surface currents in the eastern basin flow eastward along the longitudinal axis of the Lake with a slight deflection toward the U.S. shoreline. These currents are mainly wind-driven except within the influence of the Niagara River [6 km (3.7 mi) from the river origin] where hydraulic currents overrule. The principal portion of the Niagara River flow is drawn from the U.S. side of the basin. Bottom currents in the basin tend to flow in a direction opposite that of the prevailing wind direction and the resultant speeds for the surface and bottom currents in this basin are similar to those in the central basin (Hamblin 1971).

SEDIMENT LOADING

E.015
Lake Erie can be separated into two regions on the basis of sediment deposition characteristics: depositional regions, where fine-grained sediment accumulate, and non-depositional regions, where the bottom is scoured and composed primarily of bedrock, glacial till, glaciolacustrine clay, or sand (Figure E.3). In the depositional regions, the sediment consists of 50-75% clay-sized particles (<0.004 mm in diameter) and the remainder silt-sized (0.004-0.062 mm in diameter). Particle size shows a strong correlation with depth, i.e., the finest sediment is found in the deeper eastern basin, the coarsest in the western basin. Calculations for sediment loading and spatial deposition indicate that 27% of the annual loading of fine-grained sediments is deposited in the central basin whereas 50% accumulates in the eastern basin (Kemp et al. 1976). The range of annual rate of accumulation in the Lake is from 0 to 7.4 mm (Kemp et al. 1977).

E.016
Tributaries contribute heavily to the total sediment loading in Lake Erie (Table E.8). However, Kemp et al. (1977) found that 40% of the silt- and clay-sized fraction of the total input is derived from erosion of shoreline

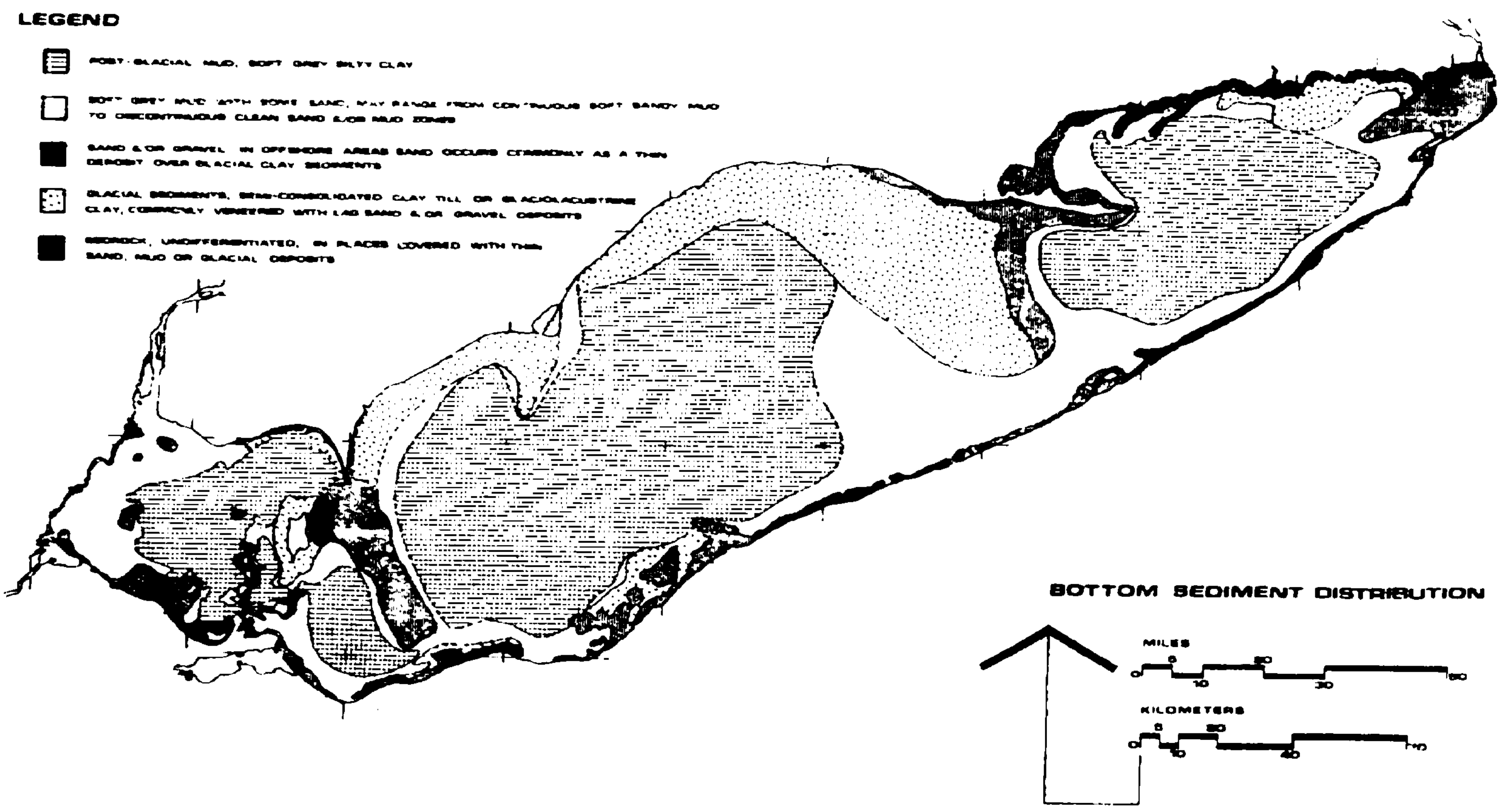

Figure E.3. Bottom Sediment Distribution in Lake Erie. Data from Thomas et al. (1976).

Table E.8. Annual Loading of Solids to Lake Erie from Tributaries[a]

U.S. Tributaries		Canadian Tributaries	
Source	Suspended Solids (MT/yr)	Source	Total Solids (MT/yr)
Black River	16,000	Grand River (Ontario)	893,500
St. Clair complex	13,000	Stoney Creek	21,250
Clinton River	13,000	Sandusky Creek	21,800
Rouge Complex	23,000	Nanticoke Creek	17,900
Huron River	23,000	Lynn River	34,700
Swan Creek complex	7,900	Dedrich Creek	8,780
Raisin River	150,000	Big Creek (Norfolk)	77,000
Ottawa River	54,000	Clear Creek	6,324
Maumee River	1,400,000	South Otter Creek	13,000
Toussaint-Portage	110,000	Big Otter Creek	87,420
Sandusky River	340,000	Catfish Creek	63,000
Huron-Vermillion	280,000	Kettle Creek	47,600
Black-Rocky	460,000	Talbot Creek	25,400
Cuyahoga River	630,000	Brock Creek	4,094
Chagrin complex	270,000	16 Mile Creek	7,000
Grand River (Ohio)	570,000	Muddy Creek	1,580
Ashtabula-Conneaut	240,000	Sturgeon Creek	6,100
Cattaraugus Creek	680,000	Cedar Creek	11,200
Tonawanda complex	320,000	Big Creek	9,700
		Detroit River[b]	27,800,000

[a]Sources of data: U.S. tributaries - International Joint Commission (1978); Canadian tributaries - Ongley (1976).

[b]A U.S. and Canadian boundary river. Source of data: International Joint Commission (1978).

bluffs and only 28% from tributaries. Their calculations suggested that of the 14.9×10^6 metric tons (MT) of fine-grained sediment entering the Lake annually, 30% or 4.5×10^6 MT was exported through the Niagara River. Although this suggests a net silt- and clay-sized sediment loading of 10.4×10^6 MT, the study presented a net loading of 14.3×10^6 MT. The authors postulated that the 3.9×10^6 MT discrepancy was attributable to an underestimation of the inputs.

MECHANISMS AFFECTING CHEMICAL BEHAVIOR OF CONTAMINANTS

E.017
Physicochemical mechanisms affecting the behavior of sediment-associated contaminants such as heavy metals and organic compounds can be classed in

three groups: oxidation-reduction (redox) potential in the sediments or overlying water column which would favor the release of reduced chemical constituents to overlying waters; diffusion of interstitial water across the sediment-water interface and release through bioturbation, gas bubbles, and wave- or wind-induced turbulence; and physical mixing by current action to distribute contaminants.

E.018
The offshore, fine-grained sediments in the Lake Erie sub-basins exhibit relatively similar physicochemical characteristics with the exception of redox potential. The electromotive redox potential usually bears a close relationship to oxygen values in overlying hypolimnetic waters (Kemp et al. 1976). The top centimeter (0.4 in.) of sediment in Lake Erie normally exhibits positive redox potentials except where bottom waters in the central and eastern basins become anoxic during summer stagnation (Burns 1976). A notable exception is an extensive area with reducing conditions at the top 1.5 cm (0.6 in.) sediment depth, extending northward from the coast near Cleveland, Ohio, and then eastward along the south shore of the central basin. This plume is the result of waste input from the Cuyahoga River and Cleveland Harbor (Thomas et al. 1976).

E.019
Typical bottom sediments in the Great Lakes probably exert little influence upon the chemistry of the overlying waters so long as the oxygen concentration of the waters at the sediment surface is 1-2 µg/mL or more (Mortimer 1971). Once these waters become anoxic, many trace elements are mobilized and can be reintroduced from the sediments into overlying water. Iron, manganese, and sulfur are mobile elements and comprise more than five percent of the total sediment by weight (Kemp et al. 1976). During anoxic conditions, these elements, along with nutrients (organic carbon, nitrogen, phosphorus, etc.), can be released to the water column (Kemp et al. 1976).

E.020
Information on the associations of metals with sediments is useful in predicting the mobility of metals to the sediment interstitial waters and release during disturbance and resuspension. When sediments are disturbed, the initial release of heavy metals comes from fractions dissolved or suspended in interstitial water, followed by easily exchangeable phases associated with the sediment particles with which they are bound. The availability of contaminants to the biota in Lake Erie depends upon the chemical phase of the substance and its proximity to the biological community.

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APPENDIX F. INDEX

APPENDIX G. GLOSSARY

Acidization (acidizing of well)--A technique for increasing the flow of oil or gas from a well; hydrochloric acid is introduced into the well to enlarge and reopen pores in oil- or gas-bearing limestone formations; an inhibited acid is used to prevent corrosion of the tubing; a blanket of calcium chloride or some other heavy inert liquid may be required at the bottom of the well to arrest the penetration of the acid downward.

API--American Petroleum Institute.

Baffle collar--A piece of hardware attached to the bottom of a casing string that is used to help control the placing (landing) of the casing; the baffle collar is a back-pressure valve which permits a floating action, thus taking off much of the load on the derrick while the casing is being run; it also prevents the backflow of cement and acts as a stop for the cement plugs.

BCF--Billion cubic feet.

Bioconcentration--Used in this report as a simplified reduction of more rigorous definitions of bioconcentration, bioaccumulation, and biomagnification, i.e., the movement of pollutants from the environment into organism tissue; no distinction is made as to whether the pollutant concentration in organismal tissue is greater than the concentration of the pollutant in the environment or whether the pollutant could be transferred through the food web to other organisms.

Bioherm--A mound-, dome-, lens-, or reeflike or otherwise circumscribed mass of rock built up by, and composed almost exclusively of, the remains of sedentary organisms (such as corals, algae, foraminifers, mollusks, gastropods, and stromatoporoids) and enclosed or surrounded by rock of different lithology.

Blowout prevention equipment--An assemblage of valves, gates, and rams (rotating head, annular preventer, pipe and blind rams, etc.) that are attached at a strategic location along a string of drill pipe and that can be hydraulically actuated to stop the flow of liquids into aud out of the drillpipe and annulus at that point.

BOP--Blowout Preventer.

Cable-tool drilling--One of the two primary methods of drilling oil and gas wells; cable-tool drilling operates on a combination hammer-suction principle. A heavy, sharp-pointed bit is raised and dropped continuously in the hole so that it chips and breaks the rock away. The bottom of the hole is kept full of mud and water, and the motion of the bit is so regulated that the moment it hits the bottom it starts up again, adding the effect of suction to the pounding.

Casing--Heavy steel pipe used to seal off fluids from the wellbore or to keep the hole from caving in; there may be several strings of casing, one inside the other, in a single well.

Collar--A structure used to protect a wellhead set below the water/sediment interface from surrounding sediment material that would otherwise collapse into the hole.

Chlorine demand--The reduction of chlorine in the presence of inorganic reducing ions, as well as the oxidation of organic aromatic compounds, ammonia and amino compounds, and cyanide in the presence of chlorine. The ultimate reaction product is chloride. The total amount of chlorine is decreased during the conversion process.

CZMA--Coastal Zone Management Act.

DEC--Department of Environmental Conservation (New York).

DER--Department of Environmental Resources (Pennsylvania).

Doghouse--The small shed near the derrick where the driller and tool dressers keep their clothes; this term is also used in offshore drilling operations for part of the deck which serves as an office and base of operations for the driller and for a compression or decompression chamber in a diving installation.

Drilling fluid (mud)--Special chemical fluids, usually called mud, introduced into the wellbore to lubricate the action of a rotary bit, to remove the cuttings, and to help prevent blowouts; drilling fluid circulates continuously down the drill pipe, into the hole and upwards between the drill pipe and the walls of the hole to a surface pit, where it is purified and begins the cycle again.

Eminent domain--The government's right and power to take private land for public use by paying for it.

Exploration--The search for oil and gas; operations include: aerial surveys, geophysical surveys, geological studies, core testing, and the drilling of test wells (wildcat wells).

FERC--Federal Energy Regulatory Commission.

Float shoe--A piece of hardware attached to the bottom of a casing string that is used to help control the placing (landing) of the casing; the float shoe also acts to prevent the casing from hanging on the side of the well as it is being lowered into the wellbore.

FUA--Powerplant and Industrial Fuel Use Act.

Hydraulic fracturing--A mechanical method of increasing the permeability of rock and thus increasing the amount of oil or gas that can be withdrawn from it. The method employs hydraulic pressure to fracture rock; it is extensively employed on limestone formations.

Hydril--A type of annular preventer (blowout prevention equipment) that can stop the flow of material through annular space.

Lenticular--Resembling a lens in shape (especially a double-convex lens); the term may be applied to a body of rock, to a sedimentary structure, to a geomorphologic feature, or to a mineral habit.

LNG--Liquified Natural Gas.

MCF--Thousand cubic feet.

MCFD--Thousand cubic feet per day.

MMCF--Million cubic feet.

NAAQS--National Ambient Air Quality Standards.

NEPA--National Environmental Policy Act.

NGPA--Natural Gas Policy Act.

ODNR--Ohio Department of Natural Resources.

On camel--Industry jargon (evolving from Canadian offshore Lake Erie drilling) referring to the process of allowing stimulated wells to flow gases and liquids to the atmosphere at the lake's surface via a hose connected between the wellhead and a bouyant device floating on the water.

Perforation gun--A device which is used to make holes in casing and cement (if present) to allow formation hydrocarbons to enter the wellbore; the gun is composed of a series of small explosive charges; it can be positioned in the wellbore adjacent to the target formation so that pellets may be shot from it through the metal and cement.

Permeability--The property or capacity of a porous rock, sediment, or soil for transmitting a fluid without impairment of the structure of the medium; it is a measure of the relative ease of fluid flow under unequal pressure; the customary unit of measurement is the millidarcy.

Polybrine--A commercially available drilling fluid composed of a polymer and calcium carbonate; this drilling fluid is used to viscify liquids and/or to reduce wellbore fluid losses.

Porosity--The property of a rock, soil, or other material of containing interstices; it is commonly expressed as a percentage of the bulk volume of material occupied by interstices, whether isolated or connected.

Post-embargo period--The period of time following the October 1973 embargo of oil exports to the United States by OPEC nations.

Prototypic esthetic setting--A hypothetical environment that contains combinations of several physical structures or elements and participant activities representative of the types of esthetic environments that may be experienced in a region.

psia--Pounds per square inch, absolute.

RCRA--Resource Conservation and Recovery Act.

Reef--A ridge- or moundlike, layered, sedimentary rock structure, or part thereof, built by and composed almost exclusively of the remains of sedentary organisms (especially corals), and normally enclosed in rock of differing lithology.

Reference Program--Realistic assumptions concerning the nature and timing of activities, and requirements for offshore rigs, vessels, and onshore facilities for the purpose of analyzing potential impacts caused by routine and accidental discharges, emissions, and wastes; the Reference Program is not a prediction of future events, but is a set of operational assumptions frozen in time for analysis purposes.

Right-of-way--A path or route which may lawfully be used; a right of passage over another's land.

Rotary drilling--The now prevalent method of drilling oil and gas wells, replacing cable tool drilling. The principle is the rotation of drill pipe at the bottom of which is fastened a bit (or cutting tool); the conical-shaped cutting tools grind a hole in the rock as the drill pipe turns. During drilling, drilling mud is in constant circulation into and out of the bottom of the hole; this mud lubricates the bit, helps prevent blowouts, and removes cuttings from the hole.

Seiche--An occasional side-to-side rhythmical movement of the water of a lake, with fluctuation of the water level.

Short-Term Exposure Limit (STEL)--The maximum concentration to which workers can be exposed continuously for a period of up to 15 minutes without suffering from irritation, chronic or irreversible tissue damage, or narcosis which would reduce work efficiency or impede self-rescue. The STEL should be considered a maximum allowable concentration, not to be exceeded at any time during the 15-minute excursion period.

SNG--Synthetic Natural Gas.

Sour gas--Natural gas contaminated with chemical impurities, notably hydrogen sulfide or other sulfur compounds, which impart to the gas a foul odor; such compounds must be removed before the gas can be used for commercial and domestic purposes.

Stimulation--See hydraulic fracturing and acidization.

Stratigraphic trap--A reservoir, capable of holding oil or gas, formed from a change in the character of reservoir rock from a break in its continuity; for example, the loss of porosity and permeability in a tight sandstone updip forms a stratigraphic trap; such a trap is much harder to locate than a structural trap because it is not readily revealed by geological or geographical surveys.

String--A number of units (drill pipe, casing, etc.) that are threaded together to form a continuous extension of pipe into a wellbore.

Structural trap--A reservoir, capable of holding oil or gas, formed from crustal movements in the earth that fold or fracture rock strata in such a manner that oil or gas accumulating in the strata is sealed off and cannot escape; used loosely in this report to include biohermal traps.

Swabbing a well--Introduction of a swab (a device equipped with an upward-opening check valve that is designed to fit snugly within the well casing or tubing) into the tubing after casing is set, perforated, and tubing run, in order to clean out drilling mud.

TCF--Trillion cubic feet.

Threshold Limit Value (TLV)--The concentration for a normal 8-hour workday to which nearly all workers may be repeatedly exposed without adverse effect.

Thumper--A device for generating seismic waves by the weight-dropping method; it is a device which drops a three-ton weight from a ten-foot elevation.

USCG--United States Coast Guard.

USCOE--United States Army Corps of Engineers.

USEPA--United States Environmental Protection Agency.

Viewshed (visual field)--All that can be seen with the naked eye from a particular reference point.

Visual impact--A change in visual character and/or visual quality over time resulting from an alteration of the landscape as viewed from the surrounding area.

Wet gas--Natural gas containing liquid hydrocarbons in solution, which may be removed by a reduction of temperature and pressure or by a relatively simple extraction process.

Wiper plug--A two-piece drilling tool that is used to isolate a slug of cement inside a string of drill pipe. One plug is placed below the cement and is designed so that when it reaches bottom and the pressure increases, the center portion shears out allowing the cement to pass through; another plug is placed on top and drilling fluid is pumped on top of the plug until the top plug reaches (bumps) the bottom plug, forcing the cement slurry into the annulus.

APPENDIX H. METRIC CONVERSION TABLE

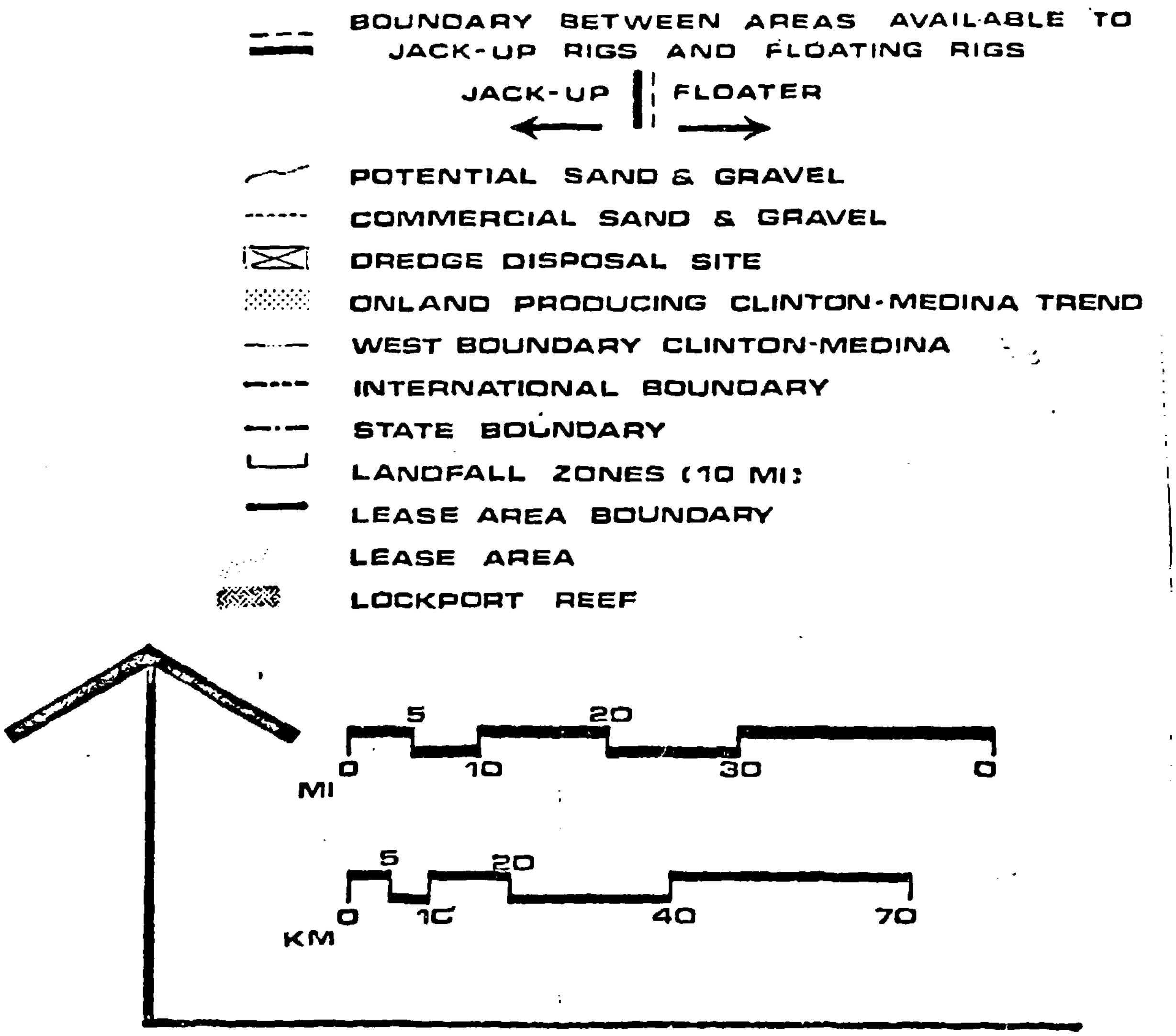
METRIC CONVERSION TABLE

Multiply	By	To obtain
Acre-feet	1.2334×10^3	Cubic meters
Acres	0.4047	Hectares
Acres	4.0468×10^3	Square meters
Barrels (bbl)	0.1589	Cubic meters
British thermal units (Btu)	1.0543×10^3	Joules
Btu per cubic feet (Btu/ft^3)	3.7234×10^4	Joules per cubic meter
Cubic feet (ft^3 or CF)	0.0283	Cubic meters
Degrees Fahrenheit (°F) -32	5/9	Degrees Celsius
Feet (ft)	0.3048	Meters
Gallons (gal)	3.7854	Liters
Gallons (gal)	0.0038	Cubic meters
Gallons per minute (gal/min)	0.0631	Liters/second
Gallons per minute (gal/min)	6.3090×10^{-5}	Cubic meters/second
Grains	6.4799×10^{-5}	Kilograms
Horsepower (electric)	7.460×10^2	Watts
Inches (in.)	2.540	Centimeters
Miles (mi)	1.6093	Kilometers
Pounds (lb)	0.4536	Kilograms
Pounds per square inch (psi)	6.8947×10^3	Pascals
Square feet (ft^2)	0.0929	Square meters
Square miles (mi^2)	2.5899	Square kilometers
Tons, short	9.0718×10^2	Kilograms
Tons, short	0.9072	Tons, metric

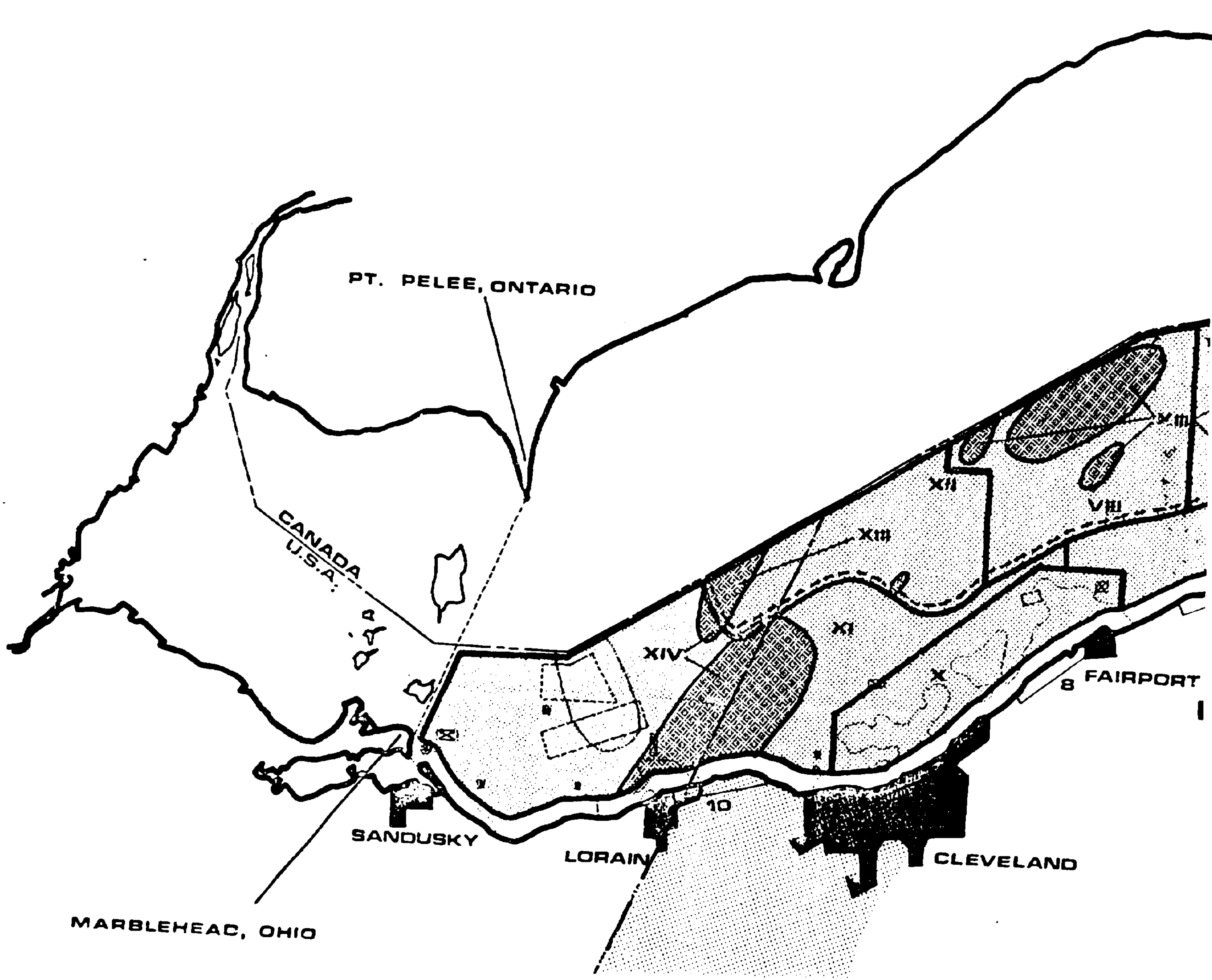
FIGURE 1-1

Summary of Geologic, Engineering, and Administrative Assumptions

Defining a Reference Program Leasing Strategy*



*Pages J-2 and J-3 must be aligned together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U.S.A.
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FAIRPORT
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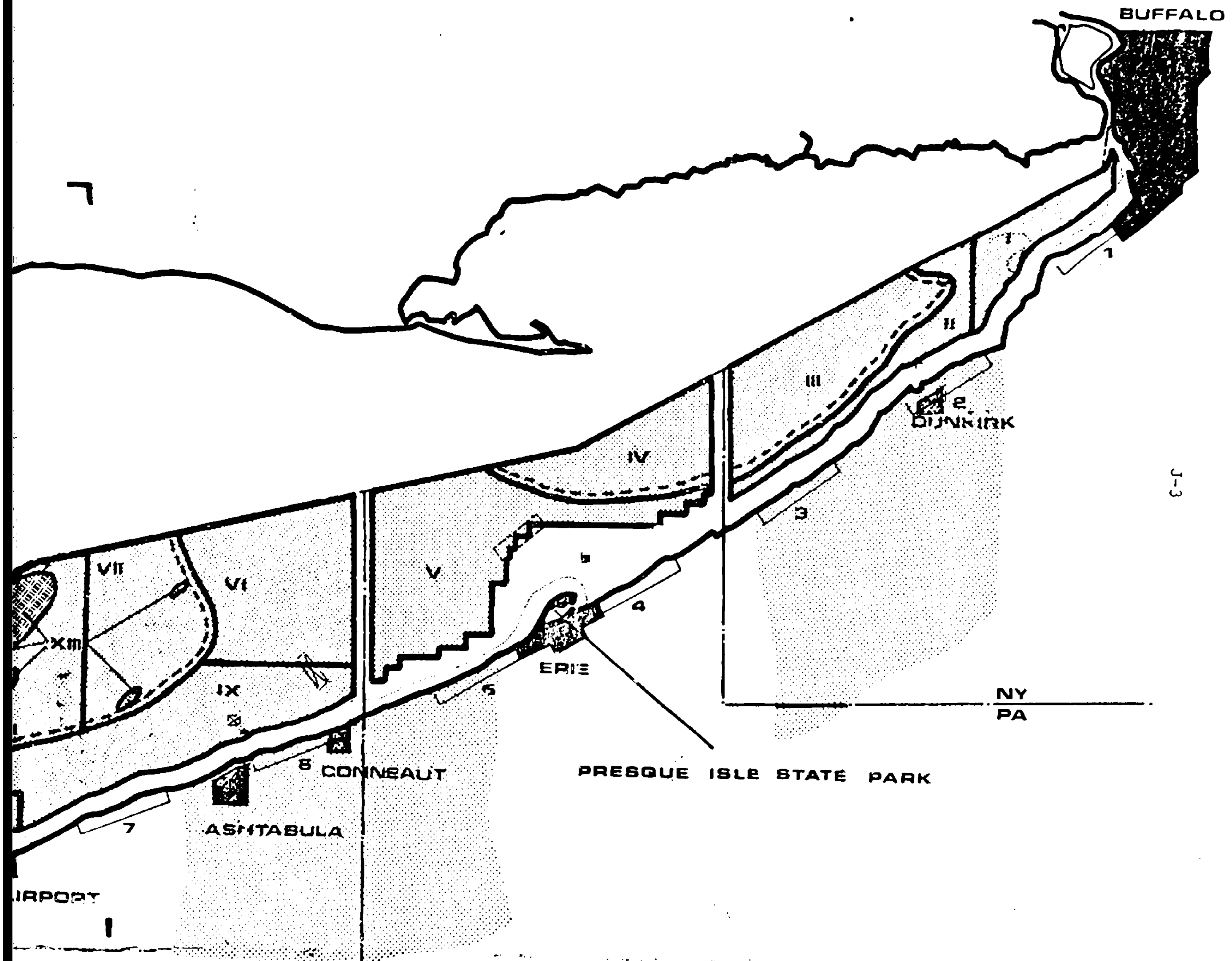
SANDUSKY
LORAIN
CLEVELAND
MARBLEHEAD, OHIO


BUFFALO
1
2
DUNKIRK
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ERIE
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PRESQUE ISLE STATE PARK
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PA
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CONNEAUT
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ASHTABULA
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